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CONTENTS

On our cover
Designed by NP Communications
Oscilloscope and waveform images courtesy of Tektronix

INSTRUMENTATION

SPECIAL REPORTS

Oscilloscopes
12 Increased insight through innovative technology
By Tom Lecklider, Senior Technical Editor

Remote Monitoring
18 Communications service providers look to test solutions
By Rick Nelson, Executive Editor

Instrumentation
22 Testing audio ADCs and DACs
By David Mathew, Audio Precision

RF/Microwave Test
28 Scope FFT and waveform math functions take on RF measurements
By Brad Frieden, Keysight Technologies

Sensors
32 Convergence drives sensor proliferation
By Rick Nelson, Executive Editor

MEDICAL TEST

Standards
34 Strict EMC rules aim for secure healthcare environment
By Bruce Fagley, EMC Technical Manager, TÜV Rheinland

COMMUNICATIONS TEST

Optical Communications Test
36 Laser, scope, and calibration instruments debut at OFC
By Rick Nelson, Executive Editor

DEPARTMENTS

4 Editorial
10 EE Industry Update
38 EE Product Picks
39 Index of Advertisers

EMC/EMI/RFI

Executive Insight
40 Managing EMC and wireless test
By Tom Lecklider, Senior Technical Editor

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Moore's Law and electronic heirlooms

April marked the 50th anniversary of Moore's Law and the arrival of the Apple Watch. Clearly, the advances in semiconductor technology forecast by Gordon Moore enable Apple to pack so much functionality into a package so small. But Moore's Law and a possible deceleration in semiconductor scaling may have unusual ramifications for consumer electronics devices in general and products like the Apple Watch in particular.

Consider that with the Apple Watch, Apple for the first time is getting into the luxury fashion business. Previously, an entry-level employee's iPhone would be identical to the CEO's. That's no longer the case, as Will Oremus in *Slate* has pointed out. Now, the employee can buy an Apple Watch for a few hundred dollars while the CEO can spend $10,000 and up.

That brings up the question, who is going to spend upwards of $10,000 for a watch that will be obsolete in a couple of years? The gold case may retain its value, but the silicon inside will not. Serenity Caldwell at iMore offers the idea of a replaceable core—you take your $15,000 watch into the Apple store every 18 months for an upgrade. But I suspect the appeal of an expensive analog watch is the intricate, accurate—and timeless (meaning "already obsolete")—internal mechanism and the craftsmanship that went into it.

In fact, makers of luxury analog brands don't seem worried about competition from Apple. Jean-Claude Biver, president of LVMH's watch division and CEO of its Tag Heuer brand, was quoted in the *Wall Street Journal* as saying he doesn't believe the Apple Watch will affect the sales of high-end mechanical watches, saying someone buys a $20,000 watch because it's a piece of art—not to tell you the time. Nevertheless, Tag Heuer is hedging its bets and collaborating with Google and Intel on the development of a smart watch.

It will be interesting to see whether Apple can solve the silicon obsolescence problem and establish its watch as an heirloom that can be handed down from generation to generation. In fact, Apple might get some help from Moore's Law. Writing in the April issue of *IEEE Spectrum*, Andrew "Bunnie" Huang says that as Moore's Law slows, we can anticipate keeping electronics products for more than a few years. Consequently, we may focus more on fashion and packaging issues than on the technology inside. Although the idea of an heirloom laptop sounds preposterous today, he writes, that might not always be the case.

That's an interesting perspective. But I think Moore's Law has a ways to go. The semiconductor analyst David Kanter offers an interesting post in his *real world technologies* blog that describes how innovations such as strained silicon, high-k gate dielectrics (HfO_2) and metal-gate electrodes, double-patterning, and FinFETs have brought us from 90 nm to where we are today, with Intel pursuing the 10-nm node. Going forward, he predicts, the industry will adopt quantum-well FETs (QWFETs), with Intel leading the way at 10 nm and others following at 7 nm.

And if the 5-nm node, achieved in a decade or two, represents a limit on planar scaling, we can increasingly adopt 3-D stacking. So I think it's unlikely that anyone will be buying an heirloom laptop or smart watch any time soon.

Apple and other manufacturers would probably prefer it that way, as an heirloom passed on represents the loss of a sale. Meanwhile, it remains to be seen if companies can develop a customer base that's willing to spend upwards of $10,000 every couple of years in pursuit of fashion and state-of-the-art technology.

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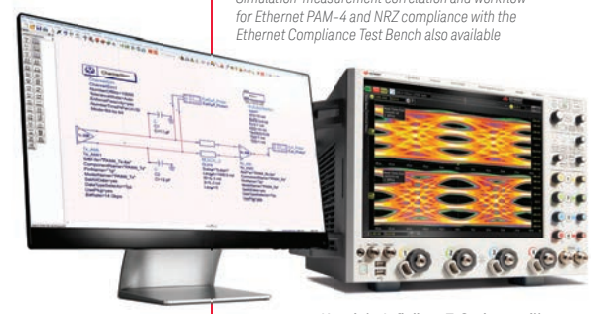

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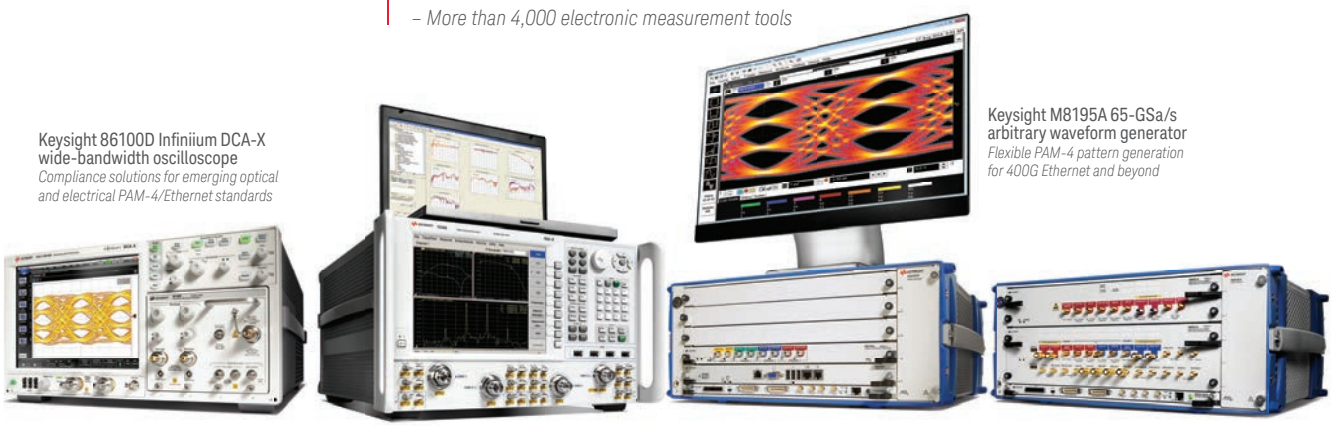

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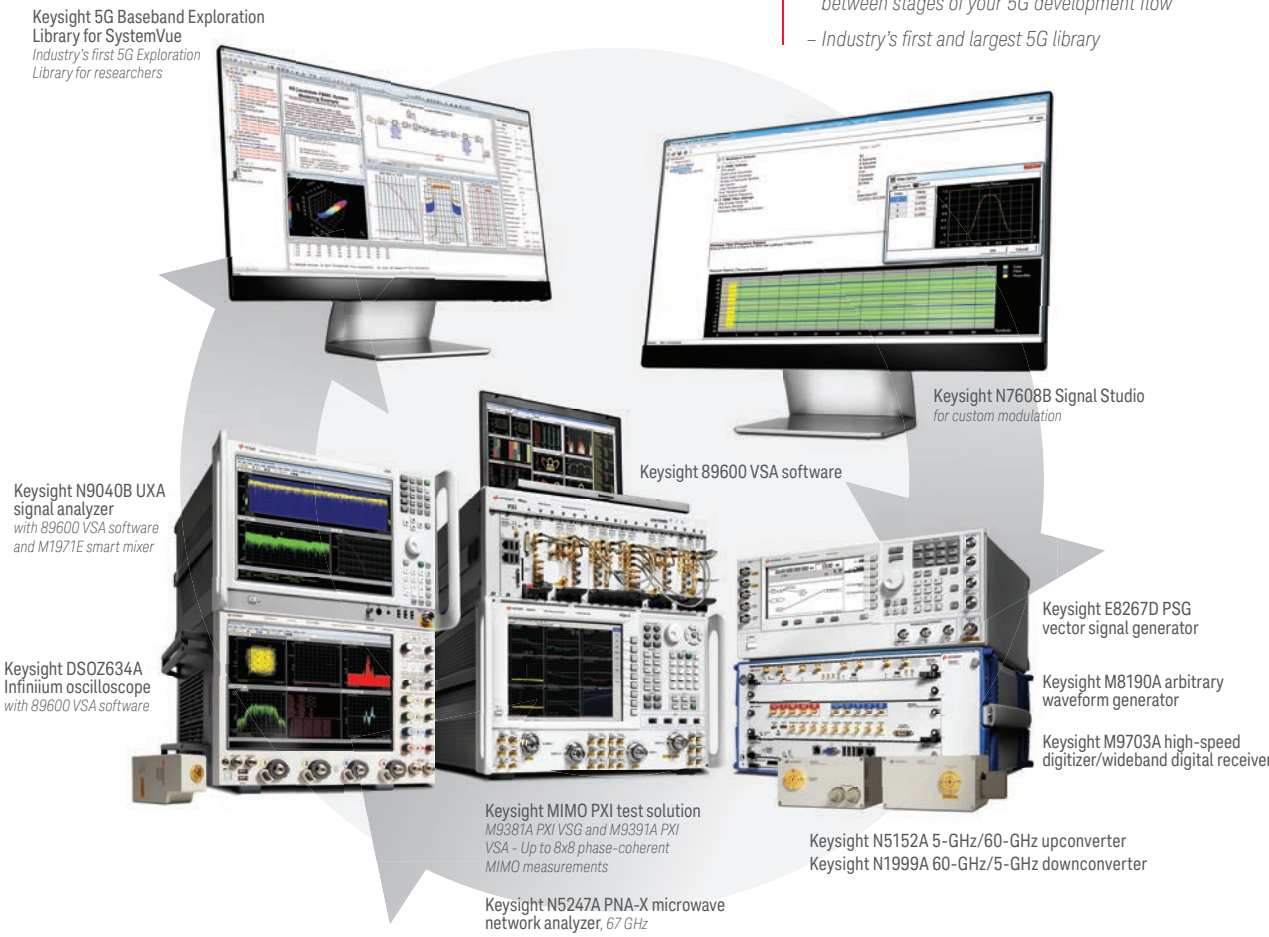
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Enterprise augmented-reality app market to grow tenfold by 2019

Juniper Research predicts that augmented-reality (AR) technology used in the enterprise will drive annual app revenues of $2.4 billion in 2019, up from $247 million in 2014.

The research notes that enterprise interest in AR has reached new heights, owing to improvements in software, wearable technology, and the promise of significant efficiency gains. However, the individual needs of enterprises dictate that AR app costs will remain high for the foreseeable future.

Despite a high revenue forecast for the sector, the research, *Augmented Reality: Consumer, Enterprise & Vehicles 2015-2019*, observed that the overall uptake of enterprise AR applications will remain relatively low until the end of the decade.

TeleGeography says global network construction resurges

New data from TeleGeography's Global Bandwidth Research Service reveals that international bandwidth grew 44% in 2014 to reach 211 Tb/s. The 65 Tb/s of new capacity deployed in 2014 is comparable to nearly the entire amount of bandwidth in service globally in 2011.

This rapid capacity growth is driven by a changing mix of global network operators. Private networks, particularly those of large content providers, account for a growing share of international bandwidth, even surpassing Internet bandwidth on the trans-Atlantic route last year. Consequently, network operation has become a core part of the business for some of the largest content providers.

USI stylus will work across multiple devices, platforms

Prominent OEMs as well as stylus and touch controller manufacturers have announced the launch of Universal Stylus Initiative (USI), an organization formed to develop and promote an industry specification for an active stylus.

The USI specification will make it possible for manufacturers to design products to a single standard, rather than the variety of proprietary approaches now in use, and it will be compatible with current notebook computer operating-system requirements. USI seeks to provide a consistent user experience while increasing the availability and consumer appeal of the active stylus through providing industry-wide interoperability and adding functions and features not supported by current styluses.

Navajo students win Schoolyard STEM Lab

Samsung and the National Environmental Education Foundation (NEEF) awarded the first-ever Schoolyard STEM Lab to the students and teachers of Nizhoni Elementary School in Shiprock, NM, in celebration of the 10th annual National Environmental Education Week.

Created by NEEF and supported by Samsung, the Schoolyard STEM Lab is an outdoor classroom space designed to work in any climate for a hands-on, immersive environmental education experience. It consists of a Growing Dome greenhouse where students can apply the scientific method to cultivation projects. The Growing Dome will not only help students better understand STEM, it also will help them make the significant connections between the natural environment and Navajo culture.

NREL purchases second AMETEK AC/DC high-power source

AMETEK Programmable Power announced that the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) has placed an order for its second regenerative AC/DC high-power source.

When installed in parallel with the previous California Instruments RS Series units purchased in 2013, the new system will have the capability to supply up to 2 MVA, making it the largest system built by AMETEK Programmable Power.

Saelig announces distribution agreement with Teledyne LeCroy

Saelig has been appointed an authorized distributor by Teledyne LeCroy, a manufacturer and supplier of oscilloscopes and serial-data solutions. The appointment will make Teledyne LeCroy oscilloscopes, arbitrary function generators, and logic analyzers available to Saelig's customer base of electronic design engineers, electronics manufacturers, defense contractors, and DoD, government, education, and individual end users. Teledyne LeCroy will work with Saelig to assist engineers and procurement professionals in choosing the best instrument for the tough product development challenges they face.

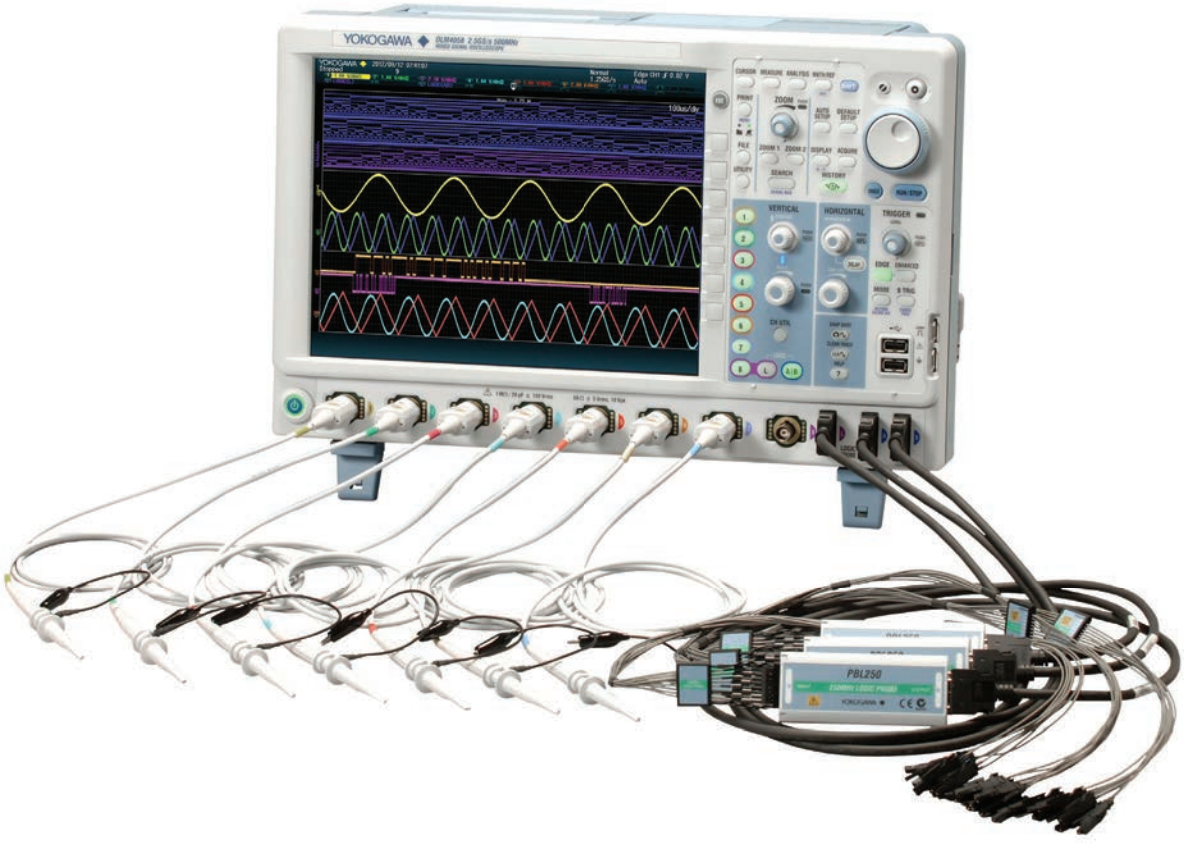
Anritsu and EMITE tout repeatable LTE lab tests

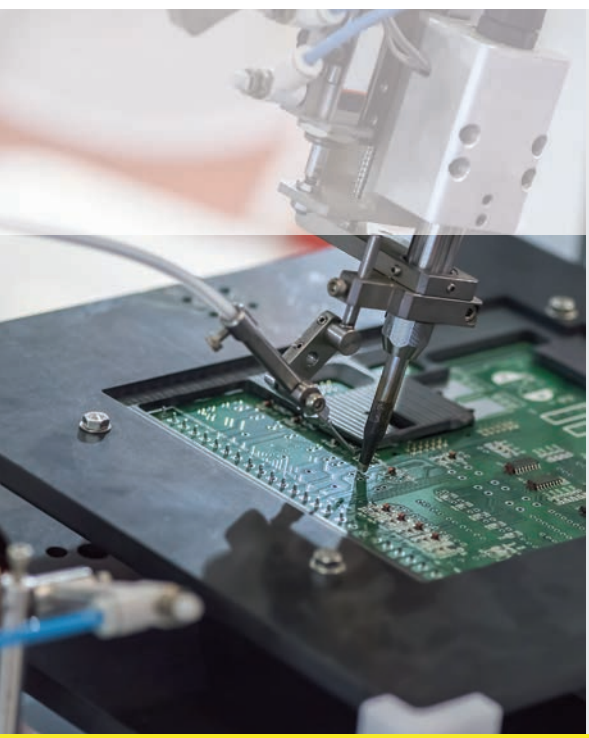
Anritsu and EMITE announced that the Anritsu MT8820C radio communication tester has been successfully used in combination with the EMITE E500 reverberation chamber and an Anite Propsim FS8 channel emulator to test LTE carrier aggregation, using 2×2 MIMO and more realistic isotropic Urban-Macro (UMA) fading profiles. The tests were performed for a leading U.S. carrier.

"We are very happy to have Anritsu's excellent MT8820C base station emulators integrated in our MIMO OTA Carrier Aggregation RC+CE test platform, as this will certainly add value to our customers," said David Sanchez-Hernandez, CEO and cofounder of EMITE. "Being able to test LTE CA + MIMO + UMA with a variety of auxiliary equipment units is a novelty worldwide and brings MIMO OTA testing to a higher level of realism and applicability worldwide."

Altera joins Industrial Internet Consortium

Altera announced the company has joined the Industrial Internet Consortium, a collaborative industry organization facilitating development of a global ecosystem for the Internet of Things. Specifically, Altera is working together with the consortium's membership on technical roadmaps to build out the Industrial Internet, a network of intelligent devices and sensors between which data can be exchanged via different connectivity protocols to drive productivity enhancements across a wide range of end-market applications.





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Increased insight through innovative technology

By Tom Lecklider, Senior Technical Editor

How does your scope answer this question: What's wrong with this signal? Typically, that's the question users want to ask, but it's not always easy to make a scope understand what you want it to do. Because oscilloscope controls affect vertical sensitivity, horizontal sweep speed, and several trigger modes, some translation generally is needed.

When we asked scope manufacturers the same question, they responded with a range of answers. Teledyne LeCroy's Chris Busso, senior product marketing manager, emphasized the increased vertical resolution in the company's HDO high-definition oscilloscopes. With 16 times the resolution of typical 8-bit instruments, these scopes should help users find small signal faults more easily. LeCroy DSOs also feature the WaveScan search and analysis tool, which you can program to look for up to 20 criteria such as rise time, nonmonotonic edges, and runts in waveforms.

Triggering was at the top of a list of Tektronix scope capabilities provided by Chris Loberg, senior technical marketing manager at the company. In addition, he included the new asynchronous time interleaving technology available in the recently launched DPO70000SX Series scopes with up to 70-GHz bandwidth. And, on the software side, DPOJET is Tek's package that addresses jitter and timing issues to help determine the root cause. DPOJET is key to the various communications-standards testing Tek scopes can perform (**Figure 1**).

Triggering also was the topic addressed by National Instruments' Christian Gindorf, senior product manager. He discussed the open FPGA architecture used in the company's PXIe 5170/71R scopes, which "… allows users to define their own custom triggers in hardware to help pinpoint elusive anomalies in the waveform. The power of the FPGA is leveraged … by giving the user complete access to the oscilloscopes' triggering architecture by allowing customized algorithms to be implemented in the trigger circuitry."

Keysight Technologies' Daniel Bogdanoff, product manager, was in no doubt when he replied, "The most important feature for top-down faultfinding and debugging is waveform update rate. The higher the waveform update rate of an oscilloscope, the higher the likelihood of seeing a glitch or error in the waveform." Several Keysight datasheets quote 1,000,000 waveforms/s update rate. Bogdanoff also mentioned the company's Zone touch trigger that allows users to graphically define a complex trigger condition on screen.

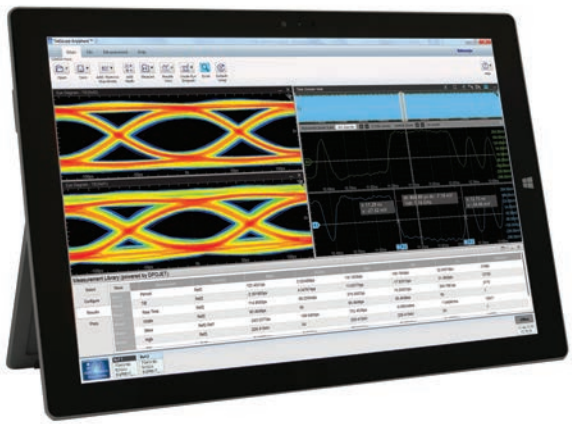

Figure 1. Eye diagram generated by DPOJET software, displayed via Tekscope Anywhere
Courtesy of Tektronix

Richard Markley, oscilloscope product manager at Rohde & Schwarz America, agreed that waveform update speed was critical, explaining that, "many times, not knowing there is an issue is [a customer's] biggest fear.… The less time the scope is working on processing and the more time it is seeing the signal, the more likely you are to find infrequent events." The company's RTO series DSOs achieve 1,000,000 waveforms/s update rate for the analog input channels.

UltraVision technology, which involves both a special chipset and associated software, is key to achieving up to 180,000 waveforms/s update rate in Rigol Technologies' scopes with bandwidths from 50 MHz to 1 GHz. Chris Armstrong, director of product marketing and software applications at the company, said, "… With the capability to test waveforms vs. a pass/fail mask or a standard trace on thousands of data frames at a time, the onboard waveform analysis features save the engineer considerable time pinpointing their underlying problem. Once the glitch or signal has been analyzed and correlated with logic signals, users can then utilize the embedded source channels to emulate and verify individual signals within the system" (**Figure 2**). An optional Arb is available on selected models.

Nevertheless, update speed is not the entire answer. R&S' Markley also discussed the need for both time- and frequency-domain capabilities. He said, "Issues may be more easily seen in the frequency domain than in the time domain, but often to … see them you need to be able to process the time-domain signal into the frequency domain quickly. Using hardware to do both digital down-conversion and calculating the spectrum of a signal greatly increases the chances of finding those elusive events."

A scope's history function was one of the features Yokogawa's William Chen, product marketing—high frequency instruments, mentioned. He said, "The history feature solves the issue of how to quickly isolate the problem waveform from all the previously acquired waveforms …. Using the history search function, users can quickly isolate, analyze, and precisely categorize abnormal waveforms without needing to carefully configure complex triggers."

Chen also commented on the benefits of built-in serial bus triggering and analysis, features found in many scopes. For example, GWInstek's Roger Lee, marketing and service department, said, "Serial bus functions help users utilize the GDS-2000E or GDS-1000B [scopes] to observe waveforms, trigger signals, and analyze low-speed serial buses (I^2C, SPI, UART, and CAN/LIN). These types of communications [buses] often are used in automotive applications."

Rather than attempting to choose the most important among a scope's features, Trevor Smith, business development manager at Pico Technology, said, "PicoScope provides good

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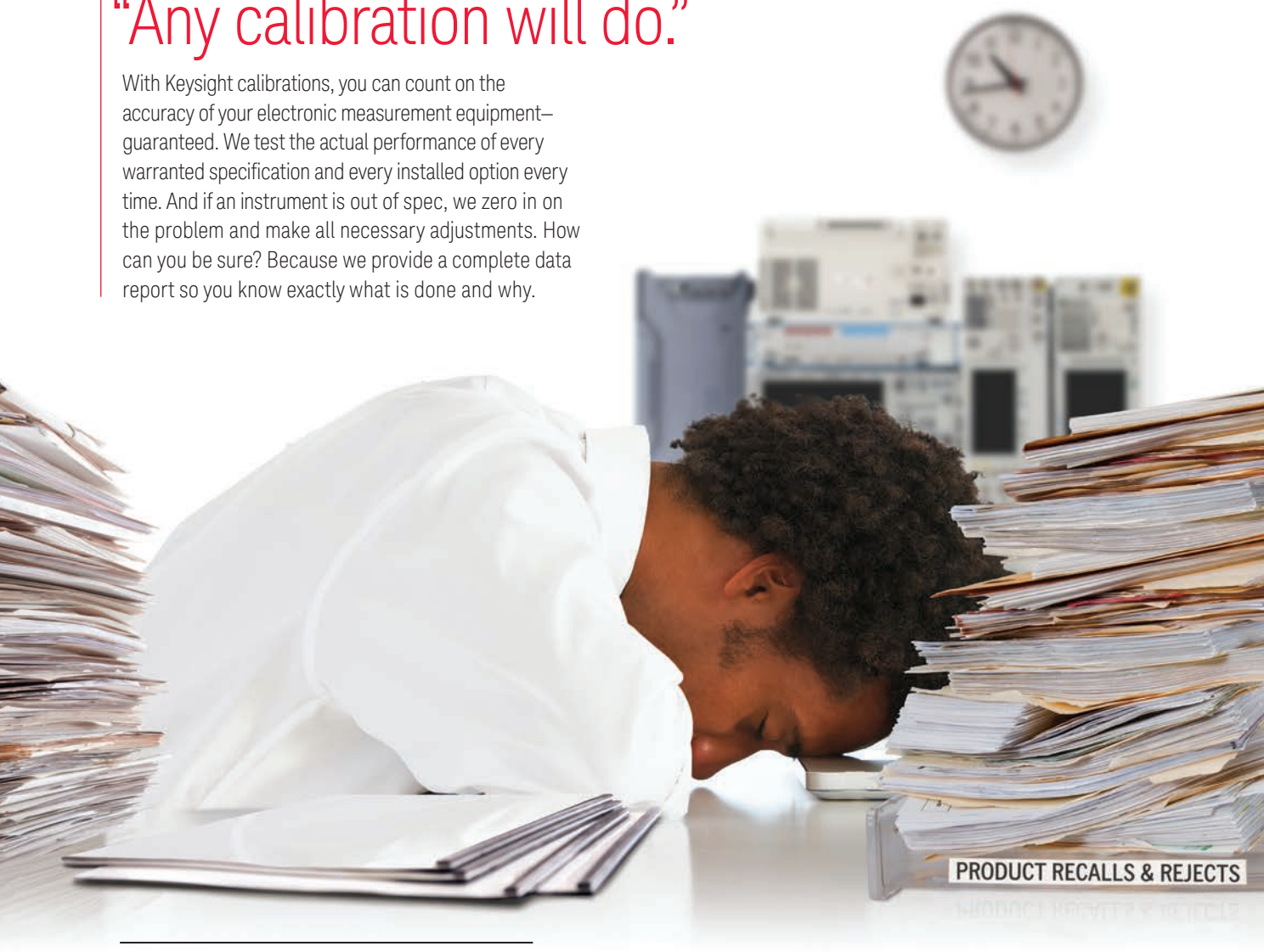

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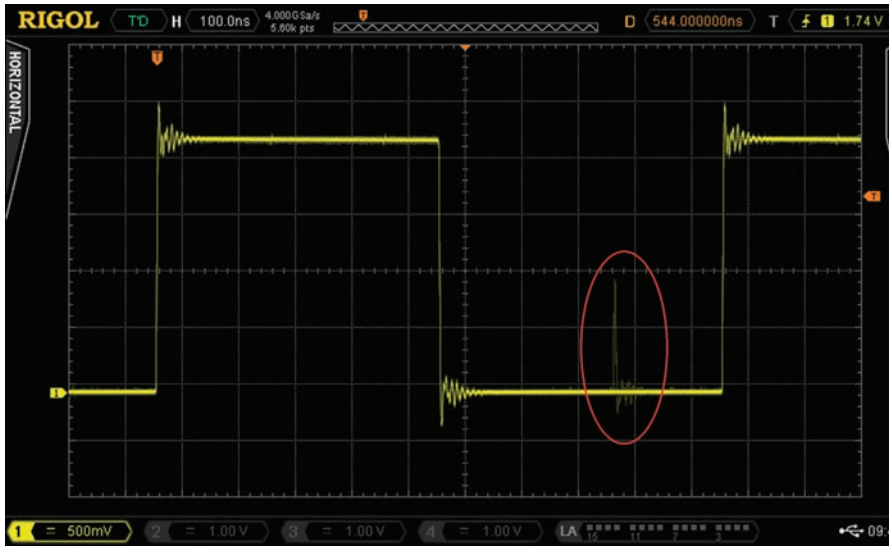

Figure 2. Intensity-graded UltraVision display showing infrequent glitch
Courtesy of Rigol Technologies

general-purpose capability, including decoding for many serial standards, automated measurements, and acquisition and display modes that are optimized for tasks such as glitch capture through to waveform streaming for ultradeep waveform analysis and unattended system monitoring applications."

Although all scope vendors acknowledge the importance of a wide range of capabilities, one scope will perform at a higher level than another in certain applications depending on which aspects the manufacturer has emphasized and how they have been implemented.

Enhanced Capabilities

Power

Many user applications have such specific characteristics that suites of scope capabilities have been developed to address them. Rigol's Armstrong listed power analysis as a key application for the company. It is addressed by adding the UltraPower Analyzer Software option to either the 2000A or 4000 Series. The option comes complete with a deskew board so users can accurately align current and voltage probe timing. Typically, voltage and current probes have very different bandwidths and delays, which, if not corrected, cause the power waveform to be in error. The software includes standard tests for power envelope and efficiency.

Also related to power, LeCroy's Motor Drive Analyzer (MDA) is a specially adapted HDO8000 12-bit resolution DSO. The company has a long history of producing scope-based analyzers for special applications such as serial data and disk drive analysis. With eight input channels, the MDA accommodates three phases of voltage and current as well as a couple of control lines, allowing more complete signal correlation. An additional 16 digital channels are optionally available, allowing concurrent torque, position, or further drive signal acquisition.

Although the MDA includes a user-configurable table of power-related measurements—real, apparent, and reactive power; power factor; phase angle; efficiency; voltage; current; and motor mechanical quantities—the overall accuracy is limited to about 1% by the scope's performance. In contrast, dedicated power analyzers typically feature 16 to 18 bits of resolution and 0.05% accuracy. Of course, these instruments also have limited bandwidth and sampling speed.

High definition

Nicolet Instruments pioneered 12-bit scopes in the 1980s and 1990s. These scopes frequently were used in biomedical experiments because the wide dynamic range afforded by 4,096 digitizing levels allowed researchers to accommodate waveforms with unknown DC offsets yet still capture sufficient detail.

All Nicolet scopes used high-resolution ADCs as do today's LeCroy HD4096 instruments to achieve the quoted resolution. However, many DSP-based techniques have been developed to enhance the performance of the much lower cost and faster 8-bit ADCs commonly used in DSOs. If a signal is repetitive, averaging successive acquisitions works well to reduce noise. One bit of resolution is added for every factor of four in the number of acquisitions: x4 = 1 bit, x16 = 2 bits.

For the majority of signals, which are not repetitive, averaging acquisitions doesn't work. Instead, successive groups of points in sufficiently oversampled data may be averaged. This approach does increase the resolution of a single acquisition, but at the expense of both lower bandwidth and a lower output sampling rate.

As noted in a previous oscilloscope special report, "Rather than averaging successive blocks of samples, averaging can be done over the first N points, then over the N points from sample 2 to sample N+1, then from sample 3 to sample N+2 and so on. This approach has two effects. First, it shortens the acquired data record by N points. Second, it maintains the original data rate. This means that peaks appear where they should rather than possibly being offset by N (fast) sampling intervals as can happen in boxcar averaging.

"A moving average is a type of FIR filter with equally weighted taps. A LeCroy application brief discussed the advantages of using a different filter tap weighting that trades slightly less improvement in noise reduction against much better frequency response characteristics. Specifically, the LeCroy ERES FIR filter tap weighting implements a shape similar to an FFT windowing function—nearly unity in the center but tapering off toward zero at the edges.

"The bell-shaped filter characteristic in the time domain has an equivalent Gaussian shape in the frequency domain. The end result is that Gibbs ringing is eliminated. The same degree of smoothing and resolution enhancement can be achieved as with a boxcar average, but the number of taps must be increased."[1]

Markley at R&S discussed the approach taken in the company's RTO DSO to enhance resolution. He said, "… [We use digital filtering that eliminates] the drawbacks of averaging and high resolution. Because it is also done in hardware prior to our digital trigger, the trigger can see the higher resolution data and trigger on it …. By [achieving] up to 16 bits of vertical resolution, this can greatly enhance the capability to see small signal details that may have a big impact on the device under test."

Figure 3. Infiniium S-Series Oscilloscope with eyediagram and jitter analysis histograms
Courtesy of Keysight Technologies

Both Keysight's 9000H and the newer Infiniium S-Series DSOs are capable of 12-bit resolution. The 9000H uses an 8-bit ADC and DSP techniques to improve resolution. The S-Series scopes (**Figure 3**) have 10-bit ADCs and offer 12 bits in hi-res mode. Noise has been considerably reduced in the newer models. For example, on the 10-mV/div range with 1-GHz bandwidth, the S-Series AC rms noise floor is 110 µV compared to 181 µV in the 9000H. Similar improvements have been made at all attenuator settings.

Pico Technology's 5000 Series DSOs provide extensive speed/resolution trade-offs. As explained on the company's website, "The PicoScope 5000 scopes have a significantly different architecture in which multiple high-resolution ADCs can be applied to the input channels in different series and parallel combinations to boost either the sampling rate or the resolution." The result is an 8-bit to 16-bit range of resolution and a corresponding range of sampling rates from 1 GS/s to 62.5 MS/s, respectively.

Standards compliance tools

As stated on the R&S website, "Jitter measurements are required for characterization and debugging of fast clock and data signals. Serial high-speed data interfaces such as USB 2.0, LVDS, HDMI, or PCI-e require a special approach for jitter measurements as they use an embedded clock signal as [the] time reference. Therefore, clock data recovery (CDR) is required to extract the frequency and phase information of the embedded clock out of the data signal.

"With the option R&S RTO-K13, clock data recovery is done directly in hardware and real time. This enables triggering on the embedded clock as well as fast histogram and eye-mask testing on high-speed serial data signals with embedded clock." The company's Markley added, "Because eye patterns are statistical in nature, doing the clock recovery in hardware greatly increases our chances of finding outliers and infrequent events that a software-based CDR may miss."

A very large number of serial bus standards are supported depending on the particular scope model. Serial triggering and decoding for low-speed buses are included as standard on

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Figure 4. Mask testing on RTO-1044 Model DSO
Courtesy of Rohde & Schwarz

many scopes. The more specialized communications buses and aviation buses, such as MIL-STD-1553 and ARINC-429, generally are options. As Tek's Loberg explained, "Serial bus decoding tools enable the engineer … to identify where control and data packets begin and end as well as identify subpacket components such as address, data, CRC, etc."

LeCroy's DDR Debug Toolkit extends the company's serial-data analysis capabilities by correctly computing DDR jitter even though the signals are bursted. Jitter parameters including Tj, Rj, and Dj are calculated across all active measurement scenarios. Time interval error (TIE) histograms, TIE track, and bathtub curves are displayed.

Measurements and masks

Mask testing was mentioned by a few companies (**Figure 4**). Teradyne's Randy Oltman, instrument product line director, said that "for well-known or expected behavior, limit and mask tests can provide a simple go, no-go test. A unique capability of Teradyne's [ZT Series] instruments is automatic mask generation, which uses a golden waveform to automatically create the upper and lower limits of a test mask." The mask testing in some Keysight and R&S models is hardware accelerated, speeding up manufacturing and statistical analysis.

In general, mask testing occurs after an acquisition has been completed. Waveform match triggering also performs limit testing, but on the fly before acquisition. The user-defined FPGA in NI's software-designed scopes allows the user to create a custom trigger solution. As the company's Gindorf explained, a specific example is a trigger that "… continuously monitors the signal acquired by an oscilloscope and is able to detect a specific signal shape without any dead time. The unique nature of the waveform match trigger is the capability to customize trigger limits in hardware, where other solutions can only provide this level of customization in a software trigger solution. This is useful for acquiring very infrequent glitches in a signal that otherwise would demand a very long acquisition and measurement time."

Measurements have been available on DSOs for many years, but they have proliferated, and some unusual ones have appeared. For example, Oltman said that more than 30 general-purpose time-domain measurements are built into the company's ZT-Series scopes. In addition, and much less common, a number of frequency-domain measurements such as SFDR, THD, SNR, and SINAD also are provided.

Purchasing considerations

It's not surprising that all scopes do a good job of acquiring and displaying waveforms given the maturity of the oscilloscope market. But many scopes offer greater value by also including extensive trigger, measurement, and analysis capabilities. However, fundamental trade-offs exist that govern the mix of features within any one model. For example, high-bandwidth direct-sampling scopes are expensive. If you have a small budget but need high bandwidth, you might consider renting a suitable scope. Or, you may be able to use a much lower cost scope with equivalent-time sampling if your signals are repetitive.

The way in which a feature has been implemented may or may not be appropriate for your application. Some scopes feature a high waveform update rate but only for short acquisitions. High resolution can be accomplished in many ways, each with significant implications. And, not all options are compatible with all scopes from a particular manufacturer. Sometimes, it's a matter of speed: There's little point in trying to use 10G Ethernet compliance software on a 100-MHz scope. In other cases, marketing decisions may restrict the availability of options for a particular scope.

Because so many variables influence the answer to what's wrong with this signal, the best way to choose a scope is to evaluate it for a reasonable period of time with your own inputs. **EE**

Reference

1. Lecklider, T., "Resolving Finer Detail," *EE-Evaluation Engineering*, July 2013, pp. 8-12.

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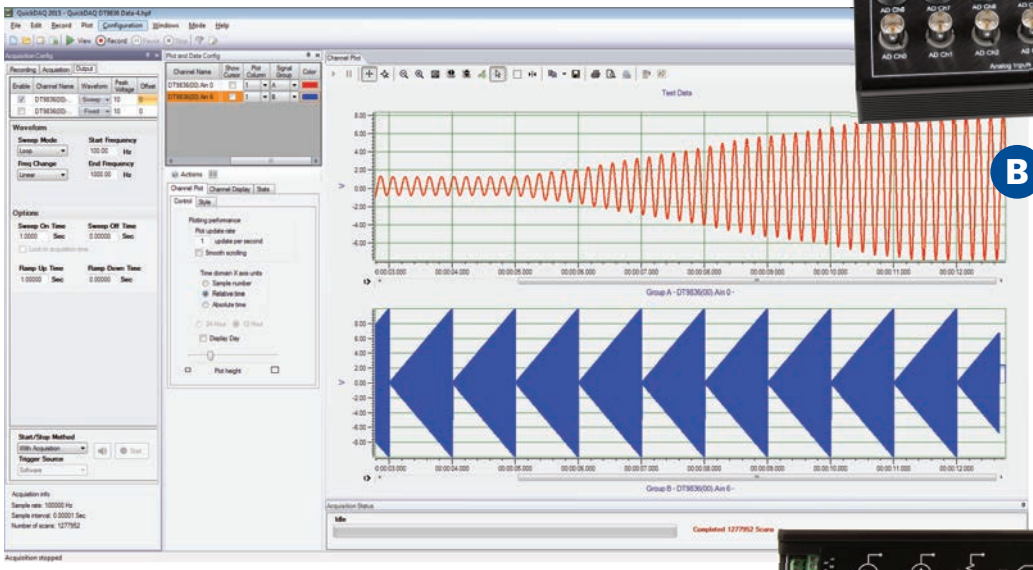

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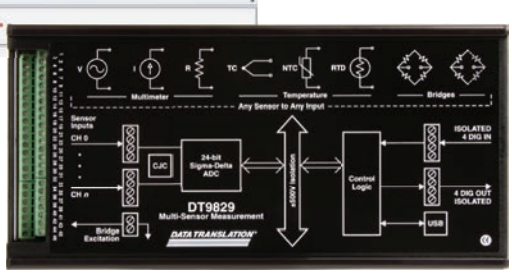

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Communications service providers look to test solutions

By Rick Nelson, Executive Editor

Wireless and landline telecommunications companies and service providers face significant challenges in rolling out, maintaining, and upgrading their networks and infrastructure to support multiple data-communication standards while maintaining the highest levels of quality for voice and data traffic. So, too, do enterprises maintaining their own networks. They need assistance in the form of instrumentation, software, and services.

Companies are facing particular challenges contending with virtualization and network transition. Consequently, virtual probes are helping to maintain visibility. Other products that companies can use range from protocol analyzers and emulators to handheld instruments that remain invaluable when a technician needs to track a problem down to a particular copper wire—and the handhelds are getting a boost from cloud computing.

New approach to service assurance

"For the communications services providers (CSPs), subscriber experience is paramount," said Karen Emery, vice president of product and business strategy at the Spirent Communications Service Assurance Business Unit. "Their end customers demand anytime, anywhere, any-device services, and high quality is table stakes. Their demand for the latest capabilities is almost insatiable. To meet this demand, the CSPs are changing the way they approach service assurance and service experience."

To assist these customers, Spirent offers the TestCenter Live 8500 (**Figure 1**), which Emery described as the first virtualized service assurance probe in the industry. Although the primary customers for Spirent's products and services are the CSPs, Emery added "… our goal is to help our customers improve the experience of their subscribers, so our focus is on holistic customer experience."

Emery said that proactive network management can offer CSPs a competitive advantage, but being proactive requires focus and investment. "Fortunately," she said, "technologies like virtualization, and our solution in particular, are evolving to deliver and support more complex services requiring greater amounts of bandwidth."

When asked about key challenges customers are facing, Emery said, "All of our customers are currently considering virtualization. One of the key challenges facing CSPs moving toward NFV [network functions virtualization] and SDN [software-defined networking] is how to continue offering a superior customer experience while the network is in transition. Our virtual probe supports service assurance for virtualized network elements but uses a consistent interface with our traditional hardware solution. It is fully integrated into our OSS [Operations Support System] and allows our customers to begin virtualizing parts of their network while maintaining visibility across the network to ensure a holistic customer experience."

She emphasized some key features of TestCenter Live 8500, including ease of use and flexibility. "The virtual probe is fully integrated into the existing Spirent TestCenter Live solution, so there is no new learning curve for the technicians using the system," she said. "In addition, CSPs can monitor their entire network, both physical and virtual assets, with one system." And finally, she said, "The 8500 is easy to instantiate when needed, so CSPs have the added benefit of turning up service assurance at

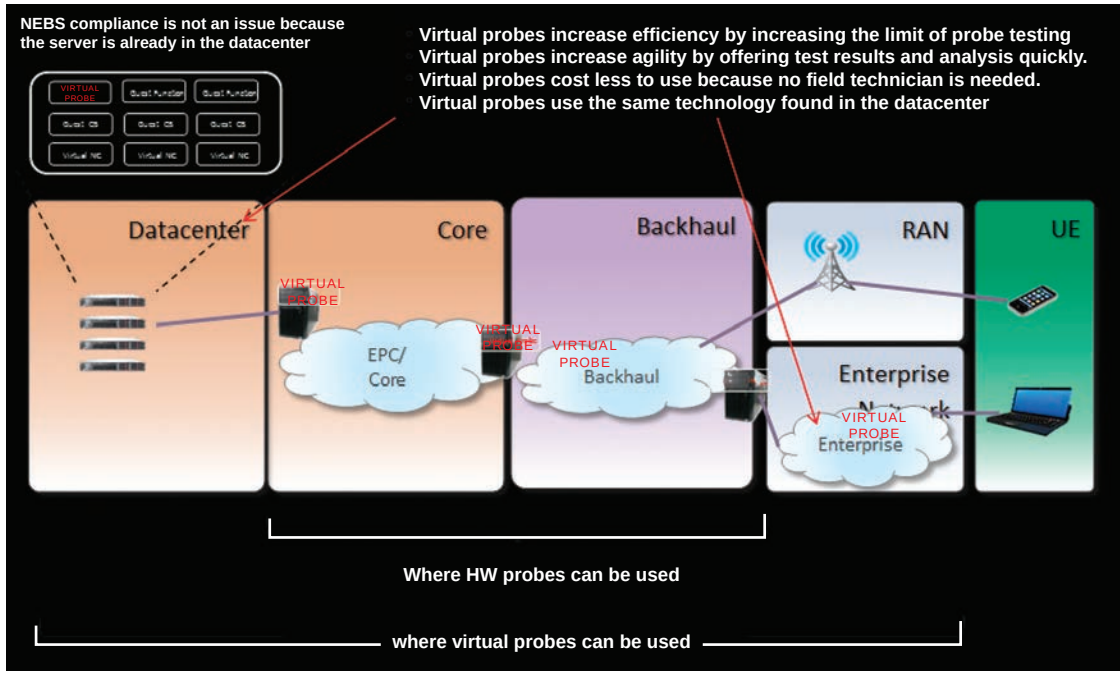
NEBS compliance is not an issue because the server is already in the datacenter
Virtual probes increase efficiency by increasing the limit of probe testing
Virtual probes increase agility by offering test results and analysis quickly.
Virtual probes cost less to use because no field technician is needed.
Virtual probes use the same technology found in the datacenter
VIRTUAL PROBE
Datacenter
Core
Backhaul
RAN
UE
VIRTUAL PROBE
EPC/ Core
VIRTUAL PROBE
VIRTUAL PROBE
Backhaul
Enterprise
VIRTUAL PROBE
Enterprise
Where HW probes can be used
where virtual probes can be used

Figure 1. TestCenter Live 8500 virtual-probe deployment
Courtesy of Spirent Communications

the same time new services are activated. This flexibility means CSPs can offer the best possible experience to their subscribers."

Voice and data test

GL Communications offers voice and data test solutions for T1, E1, T3, E3, OC-3/12 STM 1/4, and wireless applications, many centered around the company's Message Automation & Protocol Simulation (MAPS) platform. MAPS supports emulation of Mobile Application Part (MAP)—an application-layer protocol used in core networks to provide services to mobile users—as well as other protocols and interfaces.

Speaking of the company's recently announced Enhanced GSM Protocol Test Suite, Jagdish Vadalia, a senior manager for product development, said in a press release, "The Global System for Mobile (GSM) is the global standard for mobile voice and data communications," adding, "GL has solutions for the analysis and emulation of entire GSM network interfaces." The suite includes the company's GSM protocol analyzer as well as protocol emulators. "GL's MAPS MAP supports emulation of all the GSM and UMTS MAP interfaces," he said.

He added, "The test suite also provides GSM network monitoring capability on the TDM network, and the analyzer monitors calls progressing through GSM networks from a central location via a web interface along with the powerful and customizable reporting tools. The GSM protocol analyzer also supports GSM-R, a proven European mobile communications standard for railway operations used to carry railway-specific voice and data services according to EIRENE (H 22 T 0001 2) and ETSI TS 102 610 specifications" (**Figure 2**).

GL also has debuted its GSM Network Surveillance software for identifying, segregating, and analyzing different types of GSM mobile calls over TDM and IP transport networks. GL's network monitoring and diagnostic system can provide key performance indicators, failure analysis, and call trace capability and more.

Vadalia said, "GL provides a variety of solutions for network-wide monitoring and surveillance. The solution consists of intrusive and nonintrusive 'PC probes' for TDM, VoIP, and wireless networks. Probes deployed at strategic locations in a network transmit and collect voice, data, protocol, statistics, and performance information and relay this information to a central/distributed network management system (NMS)—called NetSurveyorWeb."

He added, "GL's network monitoring and diagnostic system can be used for billing verification, remote protocol analysis, and traffic engineering. It also can provide key performance indicators, failure analysis, and call trace capability. A service provider or an equipment manufacturer must have the means to perform the aforementioned surveillance tasks cost effectively, remotely, automatically, and nonintrusively. Fortunately, the network backbone contains a wealth of information that can be monitored and collected to support these activities."

Other recently introduced products from GL include T1 E1 Express PCIe analysis and emulation boards (**Figure 3**), which can monitor T1 E1 line conditions such as frame errors, violations, alarms, and clock (or frame/bit) slips. The boards support comprehensive analysis and emulation of voice, data, fax, protocol, analog, and digital signals as well as echo and voice-quality testing. The boards are available with a GUI for Windows 7 and Windows 8 operating systems with support for almost all existing T1 E1 analyzer applications.

Software and modular hardware

Tektronix Communications announced in April the addition of two new solutions, GeoSoft and GeoBlade, to its GeoProbe family. GeoSoft is a software-only, or virtual, probe that has been developed in response to a number of carrier needs, including the move toward virtualized network environments.

GeoBlade combines elastic software and modular hardware to cope with the demands of today's massive data traffic growth while providing the opportunity to scale at speed whenever needed. GeoBlade has the capability to support data transfer speeds from 10 Gb/s to hundreds of Gb/s, collecting and correlating massive amounts of data in real time.

Figure 3. T1 E1 Express PCIe analysis and emulation boards
Courtesy of GL Communications

Commenting on the announcement in a press release, Said Saadeh, who leads the GeoProbe product team at Tektronix Communications, stated, "There is a common misconception in the probing market that a one-size-fits-all approach exists. Our experience and years of learning from our existing probing business tell us that this is a fallacy as no two operators' needs are ever the same, and the requirements of tomorrow will be substantially different from what they are today." He added, "This announcement demonstrates our understanding of the new market requirements of virtualized networks. We understand that network infrastructure is changing and growing."

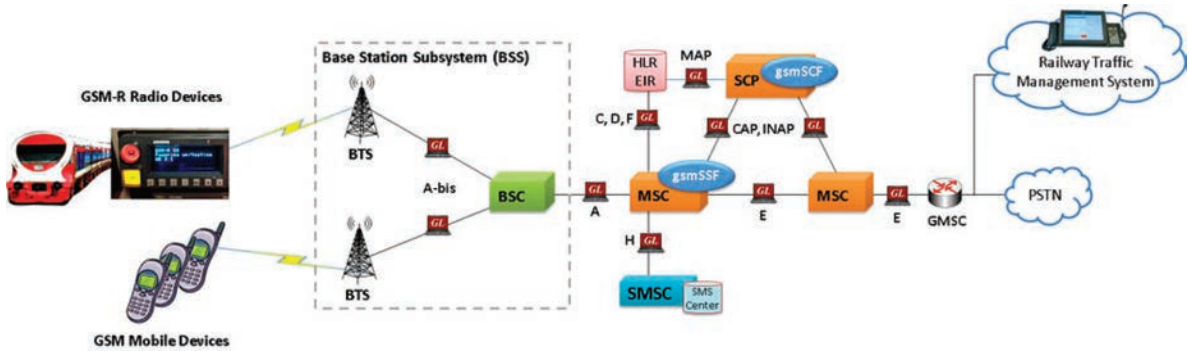

Figure 2. Enhanced GSM protocol test suite
Courtesy of GL Communications

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Figure 4. MaxTester 635
Courtesy of EXFO

For its part, Ixia announced earlier this year that it is leveraging virtualization to help enterprise IT departments ensure security resilience. The company said its BreakingPoint security resilience solution now is available as virtualized software. Offering an elastic deployment model, the new BreakingPoint Virtual Edition provides enterprise IT departments with the high-fidelity, real-world validation that vendors and service providers use to ensure network security resilience.

Ixia also released a study[1] finding that virtualization technology could pose hidden dangers within enterprise networks, with only 37% of survey respondents reporting that they monitor their virtualized environments in the same manner as their physical environment. Nevertheless, the study finds that virtualization adoption will continue over the next two years, with companies maintaining or increasing their monitoring capabilities.

In other news, at the Mobile World Congress, JDSU highlighted products that help service providers optimize the quality of LTE, mobile-video, and virtualized networks. The company introduced a scalable, real-time performance monitoring and problem segmentation solution for Ethernet networks, and it upgraded its Video Service Assurance product line, creating a software-based solution that monitors operators' video services end-to-end from the video source to the end device as part of a multiservice assurance solution.

Handheld testers meet cloud

Fluke Networks recently unveiled Link-Solutions, a combination of network testers and cloud-based reporting. Based on Fluke Networks' LinkRunner and LinkSprinter hand-held network testers, Link-Solutions provides a cohesive way for PC and front-line technicians, field-managed IT teams, system integrators, and VARs to conduct copper, fiber, and Ethernet tests and then manage their test results—regardless of which testers they used—via a unified cloud-based dashboard.

And EXFO announced that it has entered into a reseller agreement with Teletech, an Australian telecom test equipment manufacturer, with regard to the latter's TS125 Remote Far End Device digital line test set. This reseller agreement paves the way toward a solution for operators and contractors with existing methods and procedures in place where the use of a far end device (FED) complements their copper-pair quality testing.

Coupled with the EXFO MaxTester 600 series—in particular the MaxTester 610 and MaxTester 635 (**Figure 4**)—the use of the FED reduces the number of truck rolls needed to change the state of the far end of the circuit when performing measurements to assess the copper circuit quality. The EXFO MaxTester 600 remotely controls the FED, instructing it to place short, open, or any other terminations at the far end of the copper-pair circuit to properly conduct measurements.

Malcom Basell, CEO, Teletech Pty. Ltd., said in a press release, "The Teletech TS125 Remote FED perfectly complements EXFO's MaxTester 600 series and extends the range of copper-pair quality tests by removing the need for repeated travels to the far end of the line. When completing tests, the MaxTester automatically controls the TS125 to ensure the line is always terminated correctly."

"By leveraging Teletech's reliable expertise with FEDs, EXFO now is poised at a vantage point in the industry to provide a fully comprehensive solution for copper-pair quality testing," said Étienne Gagnon, vice president, Physical-Layer and Wireless Division. **EE**

Reference

1. *The State of Virtualization for Visibility Architectures*, Ixia Research Report, March 2015.

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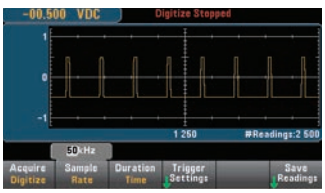
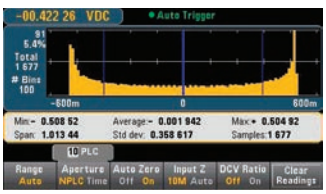


Trend chart



Histogram

Truevolt DMMs	34461A	34465A *NEW*	34470A *NEW*
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DCV accuracy	35 ppm	30 ppm	16 ppm
Linearity	2 ppm	1 ppm	0.5 ppm
Reading speed	1 k/s	5 k/s (opt 50 k/s)	5 k/s (opt 50 k/s)
BenchVue software enabled	Control your DMM with other Keysight instruments via a PC or mobile device		

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Testing audio ADCs and DACs

By David Mathew, Audio Precision

In 2015, there's not much question about audio storage, transmission, or streaming: it's digital. Apart from rare sightings of vinyl or open-reel tape in boutique sales or creative enclaves, audio is digital. Done right, digital audio is flexible, robust, and of very high quality. Pulse code modulation (PCM) recording, lossless surround formats, and even lossy compression (at least at high data rates) provide the soundtrack for our lives.

But, of course, sound in air is not digital. The pressure waves created by a human voice or a musical instrument are recorded after exciting a transducer of some sort, and the transducer responds with an electrical voltage that is an analog of the pressure wave. Likewise, at the end of the chain, the digitized audio signal must eventually move air, using a voltage that is the analog of the original sound wave to drive a transducer that creates a pressure wave.

Near the beginning of a digital chain, then, we must use an analog-to-digital converter (ADC) to transform the analog electrical signal to a digital representation of that signal. Near the end of the chain, we must use a digital-to-analog converter (DAC) to transform the digital audio signal back into an analog electrical signal. Along with the transducers, these two links in the chain (the ADC and the DAC) are key in determining the overall quality of the sound presented to the listener.

Testing audio converters

The conventional measurements used in audio test also can be used to evaluate ADCs and DACs. These measurements include frequency response, signal-to-noise ratio (SNR), interchannel phase, crosstalk, distortion, group delay, and polarity. But conversion between the continuous and sampled domains brings a number of new mechanisms for nonlinearity, particularly for low-level signals.

Of course, ADCs and DACs are used in a great number of nonaudio applications, often operating at much higher sampling rates than audio converters. Very good oscilloscopes might have bandwidths of 33 GHz and sampling rates up to 100 GS/s, with prices comparable to a Lamborghini. Although audio converters don't sample at anywhere near that rate, they are required to cover a much larger dynamic range, with high-performance ADCs digitizing at 24 bits and having SNRs greater than 120 dB. Even a high-end oscilloscope typically uses only an 8-bit digitizer. 24-bit conversion pushes the measurement of noise and other small-signal performance characteristics to the bleeding edge; consequently, measurements of such converters require an analyzer of extraordinary analog performance.

Test setups

The typical test setups are straightforward. For ADC testing (**Figure 1**), the analyzer must provide extremely pure stimulus signals at the drive levels appropriate for the converter input. For converter ICs, the analyzer must have a digital input in a format and protocol to match the IC output, such as I²S, DSP, or a custom format. For a commercial converter device, the digital format typically is an AES3-S/PDIF-compatible stream. For devices that can sync to an external clock, the analyzer should provide a clock sync output.

For DAC testing (**Figure 2**), the analyzer must have a digital output in the appropriate format and analog inputs of very high performance.

The graphs in this article were created by testing commercial converters, using the AES3 digital transport. The analyzer is the Audio Precision APx555.

As mentioned previously, ADCs and DACs exhibit behaviors unique to converters. The Audio Engineering Society has recommended methods to measure many converter behaviors in the AES17 standard. The following examples examine and compare a number of characteristic converter issues.

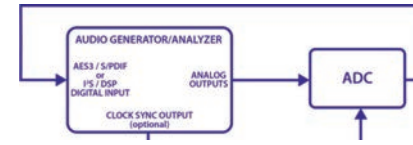

Figure 1. ADC test block diagram

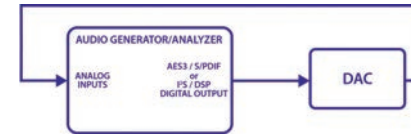

Figure 2. DAC test block diagram

Idle tones

Common audio converter architectures, such as delta-sigma devices, are prone to have an idling behavior that produces low-level tones. These "idle tones" can be modulated in frequency by the applied signal and by DC offset, which means they are difficult to identify if a signal is present. An FFT of the idle channel test output can be used to identify these tones.

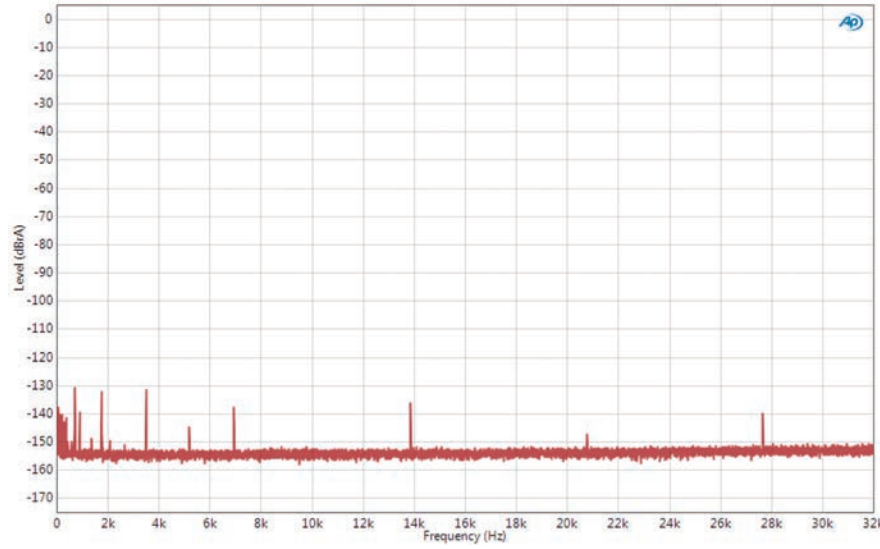

Figure 3. FFT idle channel noise, DAC A

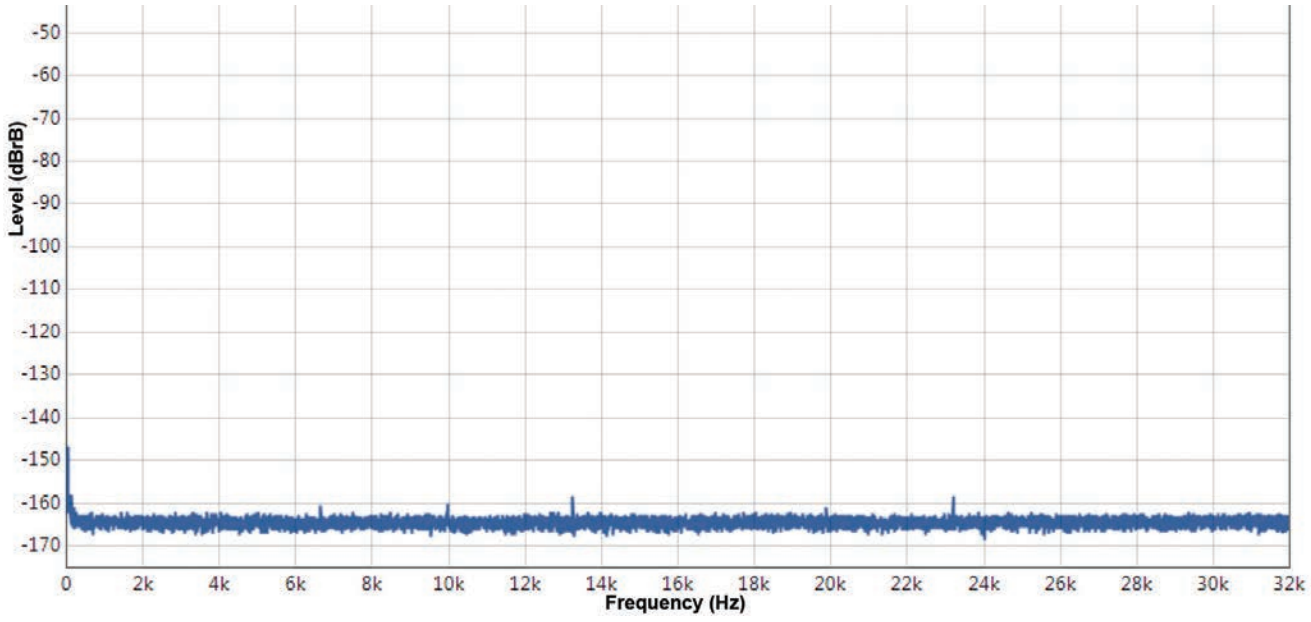

Figure 4. FFT idle channel noise, DAC B

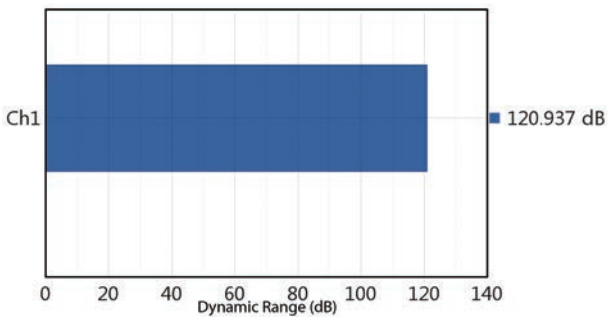

Figure 5. SNR for DAC B

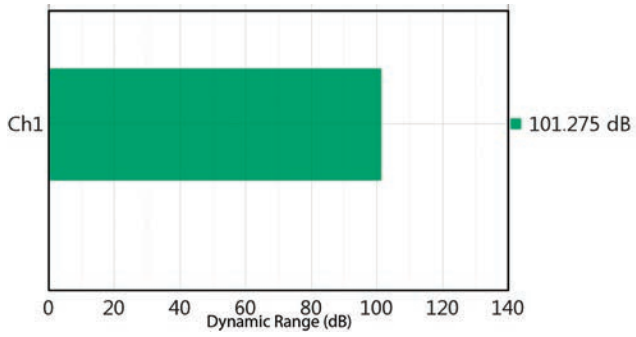

Figure 6. SNR for DAC C

The DAC in **Figure 3** shows a number of idle tones, some with levels as high as -130 dB. The idle tones (and the noise floor) in **Figure 4** are much lower.

Signal-to-noise ratio (Dynamic range)

For analog audio devices, an SNR measurement involves finding the device maximum output and the bandwidth-limited rms noise floor and reporting the difference between the two in decibels.

With audio converters, the maximum level usually is defined as that level where the peaks of a sine wave just touch the maximum and minimum sample values. This is called "full scale" (1 FS), which can be expressed logarithmically as 0 dBFS. The rms noise floor is a little tricky to measure because of low-level idle tones and, in some converters, muting that is applied when the signal input is zero. AES17 recommends that a -60 dB tone be applied to defeat any muting and to allow the converter to operate linearly. The distortion products of this tone are so low they fall below the noise floor, and the tone itself is notched out during the noise measurement. IEC 61606 recommends a similar method but calls the measurement dynamic range.

Figures 5 and **6** show a comparison of the signal-to-noise measurements of two 24-bit DACs operating at 96 kS/s using this method. As can be seen, some converter designs are much more effective than others.

Glossary

AES: Audio Engineering Society, with headquarters in New York City

AES3, S/PDIF: In the consumer and professional audio field, digital audio typically is carried from point to point as a biphase coded signal, commonly referred to as AES3, AES/EBU, or S/PDIF. There are electrical and bit-stream protocol differences among the variations of biphase coded digital audio, but the various signals are largely compatible. Variations are defined in the standards AES3, IEC 60958, and SMPTE276M.

Anti-alias filter: In sampled systems, the bandwidth of the input has to be limited to the folding frequency to avoid aliasing. Modern audio ADCs normally have this anti-alias filter implemented with a combination of a sharp-cutoff finite impulse response (FIR) digital filter and a simple low-order analog filter. The digital filter operates on a version of the signal after conversion at an oversampled rate, and the analog filter is required to attenuate signals that are close to the oversampling frequency. This analog filter can have a relaxed response since the oversampling frequency often is many octaves above the passband.

Anti-image filter (reconstruction filter): Digital audio signals can only represent a selected bandwidth. When constructing an analog signal from a digital audio data stream, a direct conversion of sample data values to analog voltages will produce images of the audio band spectrum at multiples of the sampling frequency. Normally, these images are removed by an anti-imaging filter. This filter has a stopband that starts at half of the sampling frequency—the folding frequency. Modern audio DACs usually have this anti-imaging filter

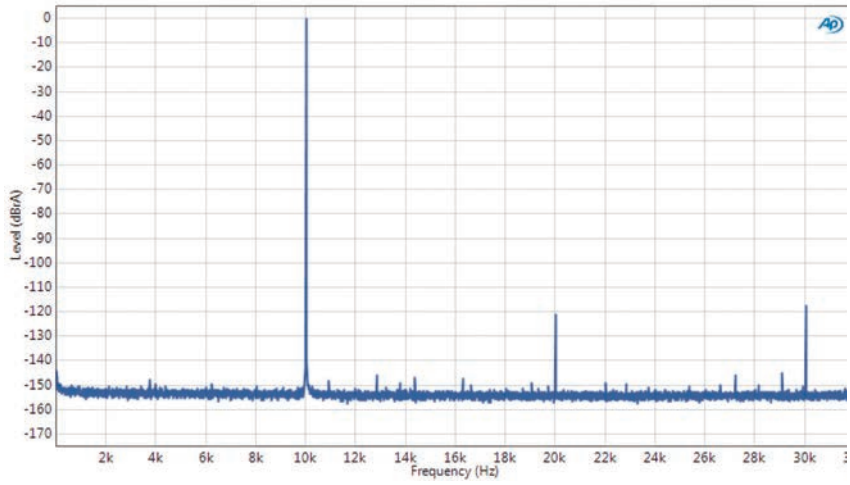

Figure 7. Jitter sidebands of 10 kHz, DAC B

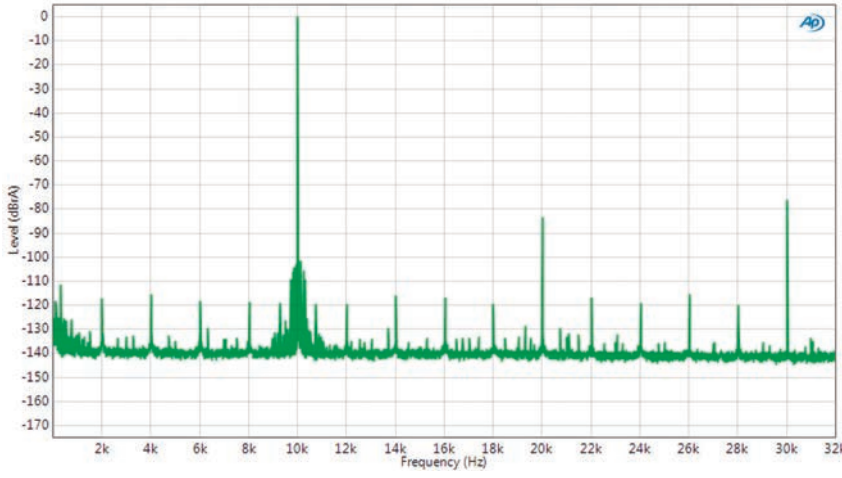

Figure 8. Jitter sidebands of 10 kHz, DAC C

implemented with a combination of two filters: a sharp cutoff digital finite impulse response (FIR) filter, followed by a relatively simple low-order analog filter. The digital filter is operating on an oversampled version of the input signal, and the analog filter is required to attenuate signals that are close to the oversampling frequency.

PCM: Pulse code modulation, a form of data transmission in which amplitude samples of an analog signal are represented by digital numbers.

UI: The unit interval is a measure of time that scales with the interface data rate and often a convenient term for interface jitter discussions. The UI is defined as the shortest nominal time interval in the coding scheme. For an AES3 signal, there are 32 bits per subframe and 64 bits per frame, giving a nominal 128 pulses per frame in the channel after biphase mark encoding is applied. So, in our case of a sampling rate of 96 kHz,

$$1\ UI = 1/(128 \times 96000) = 81.4\ ns$$

The UI is used for several of the jitter specifications in AES3.

Jitter

For ADCs, clock jitter can occur within the converter, and synchronization jitter can be contributed through an external clock sync input. For DACs receiving a signal with an embedded clock (such as AES3 or S/PDIF), interface jitter on the incoming signal must be attenuated.

Sinusoidal jitter primarily affects the audio signal by creating modulation sidebands, frequencies above and below the original audio signal. More complex or broadband jitter will raise the converter noise floor. A common measurement that reveals jitter susceptibility is to use a high-frequency sinusoidal stimulus and examine an FFT of the converter output

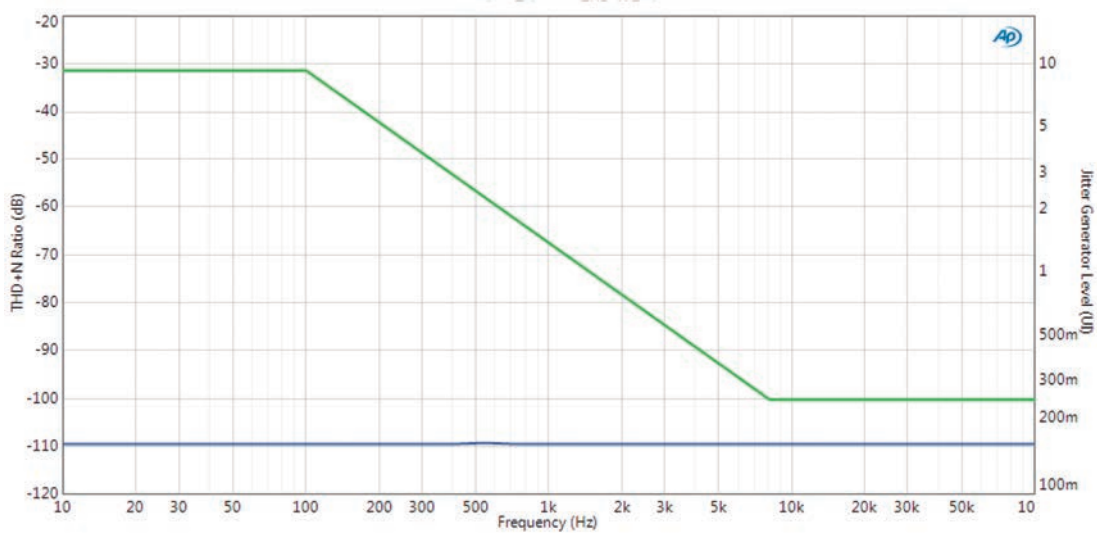

Figure 9. DAC B THD+N during jitter tolerance sweep

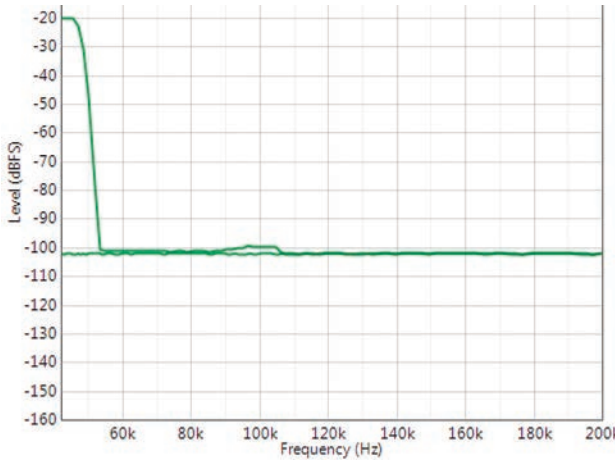

Figure 10. ADC C anti-alias filter OOB rejection

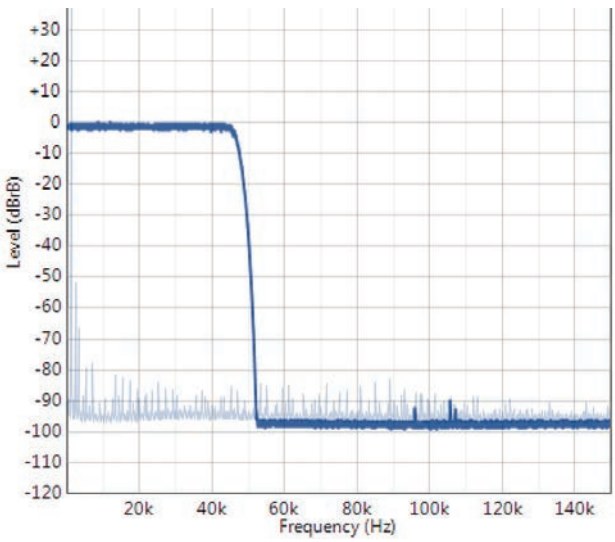

Figure 11. ADC B anti-alias filter OOB rejection

for jitter sidebands, which are symmetrical around the stimulus tone. In **Figures 7** and **8**, DAC C shows strong sidebands while DAC B shows none. Note that the strong tones at 20 kHz and 30 kHz are products of harmonic distortion and not jitter sidebands.

Jitter tolerance template

AES3 describes a jitter tolerance test where the capability of a receiver to tolerate defined levels of interface jitter on its input is examined. A digital audio signal is applied to the input. The signal is jittered with sinusoidal jitter, swept from 100 Hz to 100 kHz. As the jitter is swept, its level is varied according to the AES3 jitter tolerance template. Jitter is set at a high level up to 200 Hz, then reduced to a lower level by 8 kHz, where it is maintained until the end of the sweep.

An interface data receiver should correctly decode an incoming data stream with any sinusoidal jitter defined by the jitter tolerance template of **Figure 9**. The template requires a jitter tolerance of 0.25 unit interval (UI) peak-to-peak at high frequencies, increasing with the inverse of frequency below 8 kHz to level off at 10 UI peak-to-peak below 200 Hz.

In this case, jitter is set to about 9.775 UI at the lower jitter frequencies and drops to about 0.25 UI at the higher frequen-

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Interpretation of noise in FFT power spectra

In audio systems, noise figures generally are measured and reported something like this:

-103 dB rms noise, 20 Hz to 20 kHz BW, A-weighted

The noise signal is measured with an rms detector across a specified bandwidth. The 0-dB reference for the noise measurement might be the nominal operating level of a device but more typically is the maximum operating level, which produces a more impressive number. Similarly, weighting filters usually produce better noise figures and so often are used in marketing specifications. A weighting filter attempts to approximate the response that we humans perceive.

So let's measure the noise of DAC B using these methods. We'll make an rms measurement first across the full signal bandwidth, then across a limited bandwidth, then with an added weighting filter.

- -120.3 dB rms noise, DC to 48 kHz
- -123.9 dB rms noise, 20 Hz to 20 kHz
- -126.2 dB rms noise, 20 Hz to 20 kHz, A-weighted

But if you look at the FFT spectrum shown in Figure 4, the average noise floor appears to be about -163 dB or so. That's a big difference. What's up?

Conventionally, an audio FFT amplitude spectrum is displayed by scaling the vertical axis so that a bin peak indicates a value that corresponds to the amplitude of any discrete frequency components within the bin. This calibration is not appropriate for measuring broadband signals, such as noise power, without applying a conversion factor that depends on the bin width and on the FFT window used.

In this case, each bin is 0.375 Hz wide (sample rate of 96 kS/s divided by an FFT length of 256k points).

The window spreads the energy from the signal component at any discrete frequency, and the Y-axis calibration takes this windowing into account. For the AP Equiripple window used here, the calibration compensates for the power being spread over a bandwidth of 2.63 bins.

This can be converted to the power in a 1-Hz bandwidth, or the power density, by adding a scaling factor in decibels that can be calculated as follows:

scaling factor = 10log(1/window scaling × bin width)
= 10log(1/2.63 × 0.375)
= 4.2 dB

To estimate the noise from a device based on an FFT spectrum, you can integrate the power density over the frequency range of interest. For an approximately flat total noise (where the noise power density is roughly constant), it is possible to estimate the sum of the power in each bin within reasonable accuracy by estimating the average noise power density and multiplying by the bandwidth.

Figure 4, for example, has a noise floor that is approximately in line with about -163 dB on the Y axis. The noise power density is the apparent noise floor minus the window conversion factor or

-163 dB – 4.2 dB = -167.2 dB per Hz

The integration to figure the total noise over a given bandwidth is simple if the noise is spectrally flat. Multiply the noise power density by the bandwidth, which in this case is 20 kHz. For dB power (dB = 10logX), this is the same as adding 43 dB (= 10log(20000)), as follows:

-167.2 + 43 dB = -124.2 dB

This calculation provides a result only ½ dB different from the 20-Hz to 20-kHz unweighted measurement cited above.

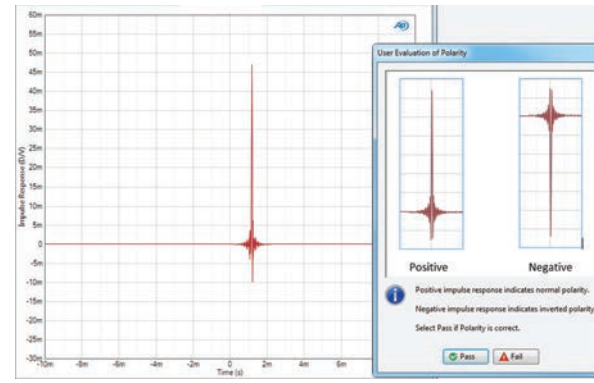

Figure 12. Using an impulse response to check polarity

cies. The blue trace is the THD+N ratio (distortion products of the 3-kHz audio tone), which remains constant across the jitter sweep, indicating good jitter tolerance in this DUT. As the jitter level rises, poor tolerance will cause a receiver to decode the signal incorrectly and then fail to decode the signal, occasionally muting or sometimes losing lock altogether.

Figure 10 shows the response of the anti-alias filter in ADC C. A tone at the input of the ADC is swept across the out-of-band (OOB) range of interest (in this case, from 40 kHz to 200 kHz), and the level of the signal reflected into the passband is plotted against the stimulus frequency. A second trace shows the converter noise floor as a reference.

For **Figure 11**, spectrally flat random noise is presented to the DAC input. The analog output is plotted (with many averages) to show the response of the DAC's anti-image filter. In this case, a second trace showing a 1-kHz tone and the DAC noise floor is plotted, scaled so that the sine peak corresponds to the noise peak.

Polarity

Audio circuits (including converters) often use differential (balanced) architectures. This opens the door for polarity faults. An impulse response stimulus provides a clear observation of normal or reversed polarity (**Figure 12**).

Summary

Tests for the high-level nonlinear behavior of an ADC are similar to those for nonlinearities in analog electronics, using standardized tests for harmonic distortion and intermodulation distortion. But audio converters bring new mechanisms for nonlinearity, particularly for low-level signals. AES17[1] and Audio Precision's Technote 124[2] describe effective testing methods for audio converter measurements. **EE**

References

1. AES17-1998 (r2009), "AES standard method for digital audio engineering—Measurement of digital audio equipment," Revision of AES17-1991.

2. Peterson, S., *Measuring A-to-D and D-to-A Converters with APx555*, Audio Precision, Technote 124, 2015.

About the author

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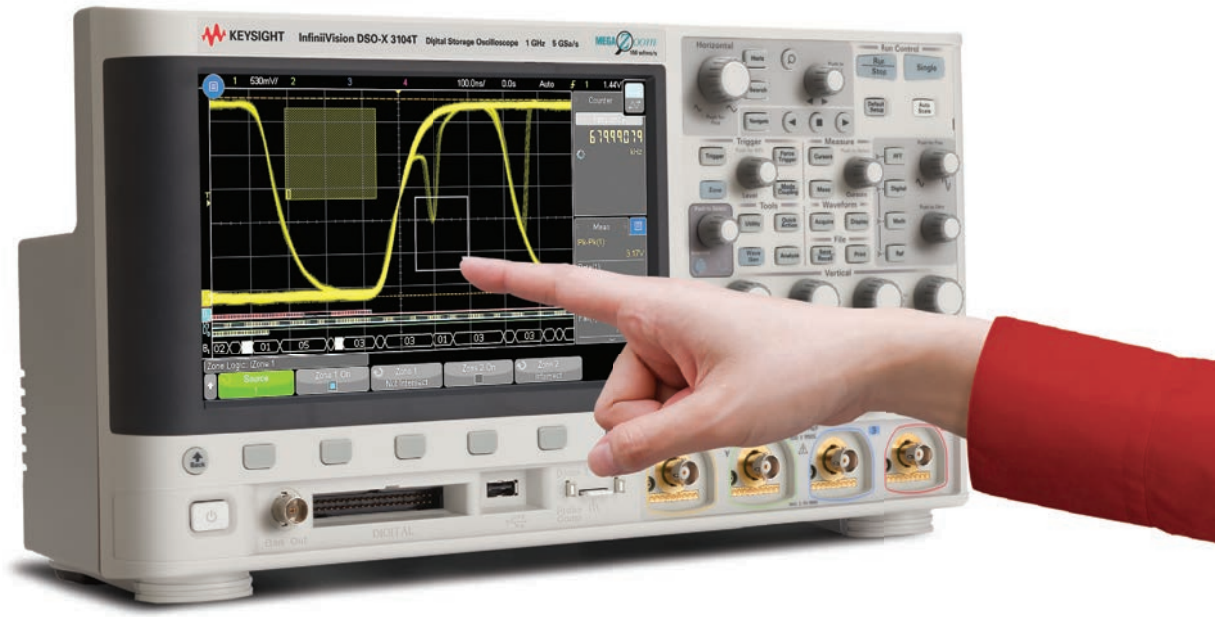

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Scope FFT and waveform math functions take on RF measurements

By Brad Frieden, Keysight Technologies

In the process of debugging and validating both digital and RF designs, the oscilloscope Fast Fourier Transform (FFT) function and a variety of other math functions can prove valuable to designers moving beyond the prototype stage and into production. For example, with digital designs, the FFT function in an oscilloscope can quickly highlight the frequency content of signals that are making their way onto power supply rails and further pinpoint the source of such noise signals with that knowledge. That's important because such signals can translate into noise in other parts of the design, cutting signal margins and potentially preventing the design from moving beyond the prototype stage until the problem is fixed.

An FFT spectral view also is helpful when looking at more complex, wide spectral signals to verify if the proper modulation is happening. Time-gated FFTs further evaluate spectral components of a signal. Math functions such as a frequency trend can quickly verify whether a classic modulation scheme is happening properly, like a linear frequency modulation across pulses in a stream. This article will explore a number of these examples and look at practical considerations for the measurements.

FFT measurement with an input sine wave

An oscilloscope that has a 1-GHz analog bandwidth and up to a 5-GS/s sample rate will be used for measurements. These are both important specifications that will tie into what kinds of measurement applications are possible. The first example measurement is the capture of a 600-MHz, 632-mV (p-p), 0-dBm, 1-mW sine-wave signal into 50 Ω (orange) and resultant FFT (white) as shown in **Figure 1**.

It's important to understand how the oscilloscope sampling characteristics play into the quality of this FFT measurement. The oscilloscope analog bandwidth, sample rate, memory depth, and related time capture period all can have a profound effect on the measurement result. This effect is heavily influenced by the characteristics of the signal under test and how those signal characteristics are related to the oscilloscope capture performance.

For example, in this simple illustration of measuring a single-tone 600-MHz sine-wave signal and wanting to see the basic spectral characteristics of that signal, the oscilloscope has to have enough analog bandwidth to minimally attenuate the amplitude of the signal. Since this oscilloscope has a maximum 1-GHz analog bandwidth, there is plenty of oscilloscope bandwidth to measure the 600-MHz tone.

To avoid aliasing in the digitizing process, sampling must occur at a rate at least twice the frequency of any appreciable frequencies present in the signal under test. In this example, a 1.2-GHz sampling rate would be required. Clearly, if the scope is sampling at its maximum 5-GS/s rate, that is more than sufficient. However, it will be shown later that for certain scope time-base settings the sample rate (and bandwidth) will decrease.

So what kind of quality is there in the FFT measurement made on the 600-MHz sine wave? Referring back to the oscilloscope FFT measurement in Figure 1, notice the main single frequency spike with a related measurement marker showing around a 600-MHz frequency and 0-dBm power. That matches expectations, but the FFT response looks very wide for a single frequency input signal.

The spacing between frequency spectrum lines in the FFT, or the width of frequency buckets that signal energy is apportioned to, is called the frequency resolution. It is based strictly on the time length of the acquired data and a factor for the FFT windowing type selected. A rectangular window is used here with a factor of 1, so the frequency resolution is simply the inverse of the record time. In this example:

Frequency Resolution = 1/(1 ns/div x 10 div) = 100 MHz

So this FFT could distinguish frequency components in the signal spectrum as close as 100 MHz, but any components closer than 100 MHz apart would merge together and be indistinguishable. That's actually a really coarse measurement.

How an increased time on screen enhances the FFT response

To demonstrate the importance of the record time upon FFT results, if the time/division is panned to 200 ns/div, with a new record time of 2 µs across the screen, the frequency resolution changes drastically to:

Frequency Resolution = 1/(200 ns/div x 10 div) = 500 kHz

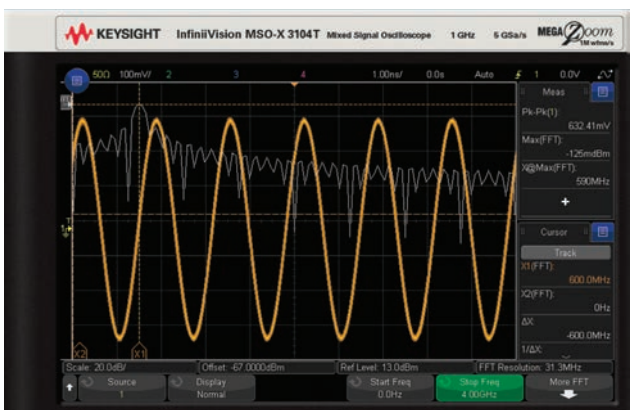

Figure 1. Time-domain capture at 1 ns/div and FFT display from a 600-MHz sine-wave input

Figure 2. Time-domain capture at 200 ns/div and resultant FFT calculation with a 600-MHz sine-wave input

The significant change in the FFT result can be seen in **Figure 2** with a much finer display of the 600-MHz frequency-domain spike. A trade-off is happening here. More time samples are being processed, the calculated FFT has more spectral lines, and better frequency resolution results. But the measurement runs slower than before to process more data—10,000 samples instead of the original 50.

Start-frequency, stop-frequency, center-frequency, and span controls

An important capability in the FFT calculation and resultant view is to be able to zoom into an area of interest for analysis. The first example had a wide span from 0 Hz to 2.5 GHz, so it was difficult to see any detail around the 600-MHz carrier. Suppose there was suspected noise around the 600-MHz carrier frequency and a desire to inspect that. The FFT controls can set a center frequency at 600 MHz and a desired span, such as 100 MHz, around the 600-MHz carrier. A start frequency of 550 MHz and stop frequency of 650 MHz also could have been selected with the same result. An FFT measurement with these parameters can be seen in **Figure 3**.

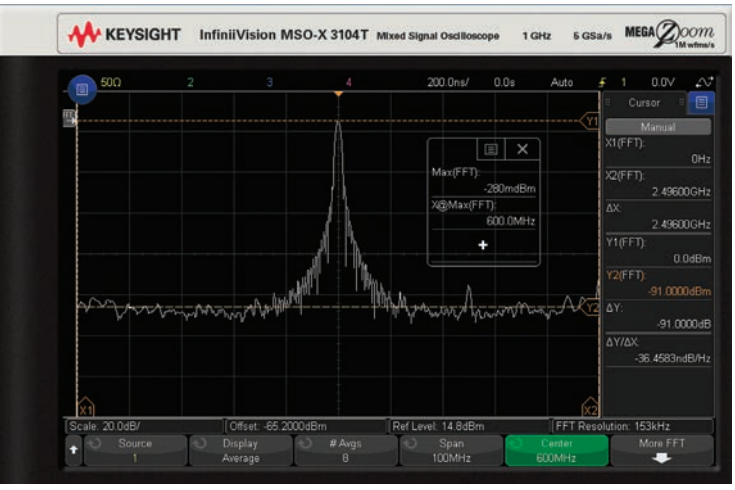

Figure 3. FFT of 600-MHz sine-wave input when FFT controls set for a 600-MHz center frequency and 100-MHz span

Wideband FFT analysis

An increasing number of today's signals have modulation present that can increase the spectral width to hundreds of megahertz or even multiple gigahertz. If spectral widths of signals are beyond around 500 MHz, then spectrum analyzers or vector signal analyzers available today do not have enough analysis bandwidth to make meaningful measurements. In such cases, an oscilloscope or digitizer is required that has enough analysis bandwidth for the application.

The carrier frequency of a signal of interest also is important. The carrier frequency of the signal under test plus half the spectral width of that signal must be less than or equal to the oscilloscope bandwidth for the oscilloscope to be used on its own for the measurement. A wideband signal frequency domain measurement will now be considered.

The signal under test is a 600-MHz RF pulse train, with 4-µs-wide RF pulses repeating every 20 µs. There is a linear frequency modulation of the signal that chirps the carrier frequency from 300 MHz at the start of the RF pulse envelope to 900 MHz at the end of the pulse envelope.

To make a basic FFT measurement of the RF pulse, the first step is to get a clean time-domain capture of a pulse from the signal on screen. The scope is reset to a known condition by pressing Default Setup. Then Auto Scale is pressed, and the time/division setting is adjusted to bring one main RF pulse on screen. The basic default rising-edge trigger is further qualified with trigger holdoff. This ensures that a trigger doesn't happen mid-pulse since that would create instability in the captured trace. The trigger holdoff is set to something slightly longer than the width of the RF pulse. The RF pulse is 4 µs wide so a trigger holdoff of 5 µs works well.

Next the FFT button is pressed to calculate a spectral view of the RF pulse train from the time-domain digitized signal on screen. There are FFT controls for start and stop frequency or center frequency and span. A wide span is first chosen with a start frequency of 0 Hz and a stop frequency of 2.5 GHz. Since this is a pulse signal, and an entire pulse can be placed on screen with only noise on the left and right side of the scope screen, a rectangular window is chosen for the FFT calculation. FFT averaging with a count of eight also helps optimize the measurement result. The FFT response that results is shown in **Figure 4**.

Markers are placed on the FFT response, and it can be seen that this RF pulse does have a wide spectral width, from 300 MHz to 900 MHz, or 600 MHz wide. What's not yet proven is that the frequency of the carrier shifts from 300 MHz to 900 MHz, linearly, from the left side of the pulse across to the right side of the pulse.

The gated FFT math function

One way to quickly see some carrier frequency values across the pulse is to use the gated FFT function. This is achieved by turning on the normal time-domain trace time gating function. This function generates a normal trace view at the top half of screen and a magnified view at the bottom of the screen. The time/division control expands and shrinks the time-gate window placed on the upper normal trace, and the time delay control moves the window along the trace. Whatever portion of the waveform is present in this window shows up in the lower trace, but magnified.

An interesting measurement results from creating a small time-width window at the very beginning of the pulse. The FFT is calculated from the data contained within the gated time window as shown in **Figure 5**.

The FFT measurement of the peak value amplitude and frequency of the spike shows that the RF pulse begins with a carrier

Figure 4. FFT of 4 µs-wide, 20-µs repeating linear FM chirp

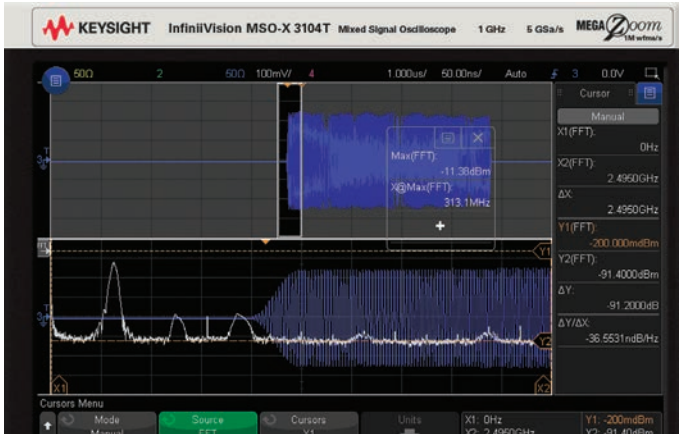

Figure 5. Time-gated FFT function observing the carrier at the beginning of the RF pulse

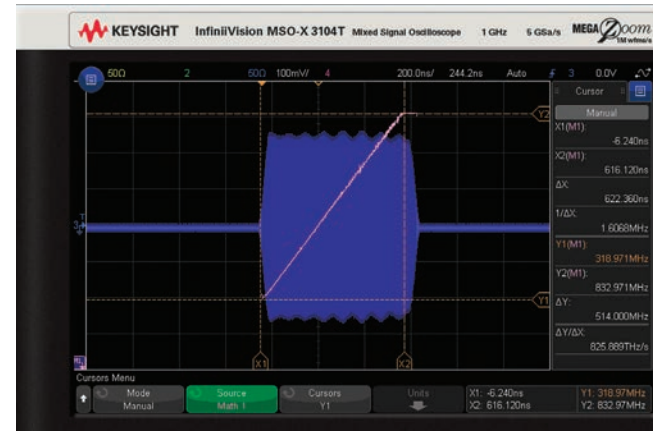

Figure 6. Measurement trend math function on frequency measurements across the pulse

frequency around 300 MHz. If the time-gate window is moved to the center of the RF pulse, the frequency is seen to be around 600 MHz. And it is 900 MHz at the end of the RF pulse. This appears to be a linear frequency-modulated chirp as desired.

Frequency measurement and measurement trend math function

In some cases, a measurement trend math function can give a helpful view of the frequency chirp profile. The oscilloscope is able to display up to 1,000 measurements in a trend format. In a similar signal example, a 600-ns-wide pulse train, repeating every 20 µs, needs to be verified. The FFT function now is turned off, and purely time-domain measurements are made.

First, the acquisition mode of the oscilloscope is changed from Normal capture to High Resolution capture mode. Second, a frequency measurement is selected from the list of possible measurements, by pressing the Measure button. A middle threshold for carrier zero crossing detection is set to 30 mV given that the swing of the carrier signal is from around -316 mV to +316 mV (1-mW signal, 0 dBm into 50 Ω). Then the Math key is pressed, and a math function called measurement trend is chosen. Markers are assigned to have their source be the math function result. An interesting view of frequency measurements taken across the RF pulse can be seen in **Figure 6**.

Clearly, the pulse carrier is shifting in a linear fashion across the pulse, from left to right, as designed. Notice that the linear ramp display is not going across the entire width of the RF pulse. This is because the 1,000 measurement limit in the trend calculation has been reached. It is important that a portion of the pulse FM function can be seen, and it is linear. For the frequency measurements across the pulse to have enough precision, it was imperative that the High Resolution acquisition mode was selected.

Summary

FFTs in oscilloscopes are a valuable tool to give a frequency-domain view of a signal. This can ultimately be done with very wide bandwidth, enabling measurements not possible with a narrower band vector signal analyzer. Example FFT measurements were able to verify that a linear FM chirp signal was shifting the carrier frequency as it should. There also was a place for other math functions, namely the measurement trend function. In this example, such a calculation allowed for a very simple verification of a linear FM chirp. **EE**

About the author

Brad Frieden is a product planner/product marketing engineer for the Oscilloscopes and Protocol Division of Keysight Technologies. He has been with HP/Agilent/Keysight for 30 years and involved in a variety of marketing roles in areas including fiber-optic test, pulse generators, oscilloscopes, and logic analyzers. Frieden received a B.S.E.E. from Texas Tech in 1981 and an M.S.E.E. from the University of Texas at Austin in 1991.

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Convergence drives sensor proliferation

By Rick Nelson, Executive Editor

Sensors Expo & Conference will celebrate 30 years of focusing exclusively on sensors and sensor-integrated systems when it convenes June 9-11 in Long Beach, CA—the expo's first time at that location. Organizers say the venue will offer attendees easy access from Silicon Valley and cutting-edge aerospace and defense, medical, entertainment, and other markets on the West Coast. The three-day event carries the subtitle "Sensing Technologies Driving Tomorrow's Solutions."

The market for sensors and related technologies is expanding at a phenomenal rate, the expo organizers report. With the convergence of MEMS, wireless, wearables, and the Internet of Things (IoT), the sales of sensors in the United States alone are expected to climb to nearly $15 billion in 2016.

In 2014, Sensors Expo welcomed 5,000 attendees from 45 states and more than 40 countries. Hot topics included the IoT, M2M, wireless, energy harvesting, and high-performance computing and communications (HPCC).[1] This year, the IoT, wireless sensor networks, and MEMS will be back with emphasis on measurement and detection, optical sensing and detection, sensor fusion, sensors at work, smart cities, and wearables.

Sensors Expo will feature more than 65 conference sessions in tracks including embedded systems, energy harvesting, IoT, MEMS, measurement and detection, optical sensing, sensors at work, wearables, and wireless.

Key presentations include "Energy Harvesting with ZigBee and NFC" by Roman Budek, product marketing, Smart Home and Energy, NXP Semiconductors; "Enabling Technologies for the Internet of Things" by Jean-Philippe Polizzi, micro and nanosystems program manager, CEA Leti; "Minimize Motion Design Using Production-Ready Building Blocks" by Jeannette Wilson, product marketing manager, Microchip Technology; "Designing Smart Medical Devices with Force Sensing Technology" by Mark Lowe, vice president of sensor business, Tekscan; "Ultra-Low Power Sensor Sampling Solutions for Energy Harvesting Applications" by Mark Buccini, director, Texas Instruments; "Using Real-Time Ethernet to Optimize Mechatronic Systems Performance" by Sari Germanos, technology marketing manager, Ethernet POWERLINK Standardization Group; and "Overcoming the Challenges of Testing in Harsh Aerospace and Industrial Environments" by Randy Martin, director, Meggitt Sensing Systems.

Sensor products on exhibit

As this article went to press, more than 200 companies were scheduled to exhibit at the 2015 event. The following have made news recently, hinting at what they might highlight at the show:

- Anaren launched its Cellular Machines line, which sends real-time sensor data over a cellular network where it can be received on mobile devices or reviewed on desktops via a cloud server.
- Coto Technology at MD&M West 2015 released its RedRock RR100 MEMS-based magnetic reed sensor, which has a number of medical device applications, including portable insulin pumps, capsule endoscopes, hearing aids, insulin pens, medical wearables, and other small, battery-powered medical devices.
- Omega Engineering recently debuted its UWBT Series Bluetooth transmitter, which measures sensor inputs such as thermocouple, RTD, relative humidity, and pH and transmits the data to a smartphone or tablet via wireless Bluetooth communication from the free UWBT app running on an iOS or Android smartphone/tablet. The company also recently debuted the PX509HL Series industrial differential pressure transducers specifically designed to provide long life in demanding industrial areas.
- Texas Instruments is offering its MSP430i202x mixed-signal microcontroller through Mouser Electronics for applications including smart meters, power monitoring and control, and precision sensors.
- Analog Devices recently announced that Elster has selected ADI's ADF7241 smart-metering solution for use in gas and electricity meters that Elster is designing as part of a nationwide energy efficiency initiative sponsored by the British government.
- Linear Technology said its SmartMesh IP on-chip software development kit enables users to develop C-code applications for execution on SmartMesh IP motes (wireless sensor nodes).

Keynote presentations

This year's conference will include two keynote speakers. First, Dr. Mike North, the host of Discovery Channel's "Prototype This," "Outrageous Acts of Science," and "In The Making," will present a talk titled "Your Sixth Sense of Innovation" on Wednesday, June 10, at 9 a.m. "The sensors market is poised for explosive growth in 2015 and beyond," he said in a press release. "To keep pace with this rapid growth rate, the Sensors Conference offers an ideal opportunity to educate and inspire the engineering community on the critical technologies that will transform not only key business processes, but how we live our lives today. I am thrilled to be part of the event that highlights the increasingly innovative role of sensors and connects this community to inspire real change."

North holds several degrees in science and engineering, including a Ph.D. in nanotechnology, and his work has been published in many peer-reviewed journals, including *Nature*. He has founded and cofounded several organizations including Galapagos, North Design Labs, Nukotoys, and ReAllocate.

The second keynoter will be Gadi Amit, the designer behind projects such as Google Project Ara, Fitbit fitness trackers, and the Lytro camera. In a 9 a.m. session on Thursday, June 11, titled "Why the Sensor Explosion Needs Technology Design," he will comment on wearables, the IoT, home automation, and mobile and cloud computing, and he will explain how to make wearables work and the key role of emotional intelligence as well as rational thinking.

"The surge of innovative sensing technologies coming out marks an ongoing paradigm shift that's changing how we'll live and interact with our environments," Amit said. "The Sensors Conference offers a deeper look at the breadth of solutions available, helping us dive into not just 'how' but 'why' design and engineering choices should be made. I look forward to connecting with my colleagues and advancing the conversation as we discuss what helps make a truly impactful experience for wearables, IoT, and cloud computing." **EE**

Reference

1. Lecklider, T., "Sensors support tomorrow's technical advances," *EE-Evaluation Engineering*, August 2014, p 8.

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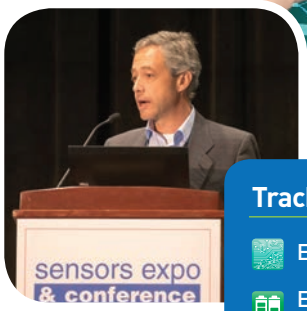

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Strict EMC rules aim for secure healthcare environment

By Bruce Fagley, TÜV Rheinland

Prevention is better than cure, and the fourth edition of IEC 60601-1-2 certainly takes that to heart. The updated standard introduces many technical changes for electromagnetic compatibility (EMC) requirements for medical devices with an eye toward ensuring that EMC phenomena do not interrupt or jeopardize safe healthcare delivery in today's technologically complex environment.

The new standard comes into force in April 2017 in the United States and Canada, and it has been reported that the U.S. Food and Drug Administration (FDA) already not only accepts the fourth edition but asks for it on new 510(k) applications. The compliance date for the European Union has not yet been announced but is expected shortly; some in the industry speculate it may be August 2017. This article explains the fourth edition's technical changes and how they will affect the testing and certification process.

ECG machine, which would need to meet new EMC rules if brought to market in April 2017

A new EMC paradigm

Medical device manufacturers will notice that the fourth edition's technical changes stem from the new EMC paradigm. Tests and limits are set according to risk and intended use, not according to a device type. The environment of intended use must be specified in the test report and can include a healthcare facility, home, and a special environment such as military, heavy industrial, or medical treatment area with high-powered medical equipment. The home environment comprises almost everything except the healthcare facility, such as restaurants, shops, schools, churches, libraries, vehicles, train and bus stations, airports, hotels, and museums. Medical devices will be tested based on their intended use, and equipment designed for special environments may need to be tested for immunity at levels higher or lower than the levels specified for the healthcare and home environments.

A closer look at EMC risks

Section 4.1 and Annex F of the fourth edition require that manufacturers include EMC risks in the risk management file, which the test laboratory now needs to review. The laboratory's responsibility is to ensure the device maker adequately addressed all EMC risks without actually evaluating the file.

While the fourth-edition requirements cover the usual EMC phenomena, manufacturers are encouraged to consider other EMC risks specific to the environment of use in their risk analysis. That means the product may need to be tested to other EMC standards, such as IEC 61000-4-16 and MIL-STD 461.

Additionally, section 6.2 of the standard instructs the manufacturer to provide an EMC test plan to the laboratory. Table G1 of section 6.2 explains what to include in it. As with the risk-management file, the EMC lab does not evaluate the test plan but must follow it to the letter. Manufacturers can refer to Annex G for guidance on writing a test plan, which needs to be included in the test report.

In addition to the test plan and risk-management file, manufacturers must supply the test lab with a more in-depth description of the device's essential performance; specify detailed, product-specific performance criteria for use during the immunity testing; write a specific plan allowing for monitoring the performance of the device during immunity testing; and supply a copy of the instructions for use and accompanying documents for review (per Section 5).

A checklist of technical changes

The normative references to the basic standards were updated, triggering some technical changes on top of the standard's actual modifications. Here is a checklist of updates.

- Connector pins need to be tested for ESD if they are accessible by the standard test finger.
- Immunity testing of DC inputs now is required, and 12-VDC inputs must be surge tested.
- The test levels for magnetic field immunity on medical products are increased to 30 A/m.
- Voltage dips and variations now are synchronized at 45-degree increments of the AC line.
- Fast transient immunity tests must be performed at a 100-kHz repetition rate instead of a 5-kHz rate.
- Conducted immunity levels are increased from 3 Vrms to 6 Vrms in the ISM frequency bands.
- Radiated immunity is specified to 2.7 GHz instead of 2.5 GHz, and modulation now is 1 kHz, in line with requirements in similar EMC standards.
- ESD immunity levels are increased significantly to 8-kV contact to metal surfaces and 15-kV air discharge to plastic nonconductive surfaces.
- A new wireless coexistence test increases the radiated immunity test levels to 28 V/m at spot frequencies from 385 MHz to 5.8 GHz per Table 9. These levels are increased to assess the product's susceptibility to interference from common wireless devices used within 30 cm. The wireless proximity test is more severe than the old FDA wireless coexistence test.
- AC line immunity tests are performed at only one line voltage instead of two voltages specified in the third edition.

• A new requirement considers patient-connected tubes filled with conductive liquid as cables and instructs they be tested for conducted immunity. Manufacturers can refer to Table 7 for specifications. Medical device manufacturers should take note that the FDA does not accept the immunity testing exclusion for signal cables less than 3 meters long and requires cables be tested.
• Wireless communication devices must have the wireless function on during the immunity testing.
• The fourth edition includes a new Table 1 showing at what line voltage immunity tests must be performed.

Information technology in medical equipment

According to section 4.2 of the fourth edition, information technology equipment (ITE) that does not affect the basic safety or essential performance of the medical system can be evaluated to the ITE standards EN 55022, EN 55032, and EN 55024, which require testing above 1 GHz.

If ITE affects the basic safety and essential performance of the system, then it must be tested to IEC 60601-1-2, which references CISPR 11 edition 5.1, and likely will not need to be tested above 1 GHz (unless the system was classified as Group 2). Some equipment categories, such as Group 2 and devices operating above 400 MHz, require testing above 1 GHz for emissions.

Testing for immunity below standard levels

Manufacturers will likely find it more challenging now to specify immunity levels lower than standard levels in their test plans and justify them via risk management. Annex E in IEC 60601-1-2 describes how to justify immunity test levels deviating from the standard. The explanation will need to consider the environment of use. For example, equipment designed specifically for use in a humidity-controlled environment may be allowed to meet lower ESD immunity levels.

Is it going to cost more?

The fourth edition will require some additional testing, thereby adding costs. If manufacturers provide the lab with the test plan based on their risk analysis during the quoting stage, the lab can respond with the most accurate estimates. In instances where the product was recently tested to the third edition, the manufacturer may be able to limit its testing to the differences per the fourth edition. Naturally, some products may still need to be completely retested if their risk analysis includes additional EMC risks.

Next steps

Manufacturers are advised to evaluate their designs now for future compliance, particularly if they have several products that will all need to be retested at some point. In some instances, testing to additional EMC standards may be required because of the need to consider all possible EMC risks in the risk analysis. Advance planning will help make the compliance process—and any design alterations, if necessary—less stressful and less likely to cause delays in getting products to market. **EE**

About the Author

Bruce Fagley is the EMC technical and operations manager, EMC East, at TÜV Rheinland, responsible for technical matters of the company's five North American EMC facilities and operations of three EMC laboratories in the East. Fagley began his EMC career 30 years ago as an international compliance engineer, and his employment at TÜV Rheinland spans 20 years. He is the author of several articles on EMC matters and the EMC notified body representative for TÜV Rheinland of North America. bfagley@us.tuv.com

Laser, scope, and calibration instruments debut at OFC

By Rick Nelson, Executive Editor

OFC marked its 40th anniversary when it convened recently in Los Angeles. The event, which show organizers describe as "the largest global conference and exposition for optical communications and networking professionals," attracted 12,375 registered attendees and 560 exhibitors occupying 106,000 square feet of exhibit space.

"We couldn't be happier to cosponsor a conference of this quality and this impact," said Optical Society CEO Liz Rogan, who also thanked cosponsors IEEE Communications Society and IEEE Photonics Society, which is celebrating its 50th anniversary.[1]

EE-Evaluation Engineering was unable to attend the event, but we did track down test-equipment vendors to see what products and technologies they introduced at the show.

Tunable laser source

Keysight Technologies highlighted its 81606A tunable laser source, a new module for the 8164B lightwave measurement system **(Figure 1)**. Tunable lasers, in combination with optical power meters and a polarization controller, can measure the filter slope, isolation, polarization dependence, insertion loss, and reflectivity of multiplexers/demultiplexers, channel interleavers, and wavelength-selective switches used in reconfigurable optical-fiber networks.

Figure 1. 81606A tunable laser source in an 8164B mainframe
Courtesy of Keysight Technologies

According to Stefan Loeffler, strategic product planner for the Keysight Digital and Photonic Test Division, speaking in a phone interview before OFC, the new product offers subpicometer tuning repeatability and best-in-class wavelength accuracy to help validate more devices per hour and speed up automated adjustment of wavelength-selective devices. The company's N7700A software suite activates the laser and power meters within a measurement system for single-sweep polarization testing. In addition, Loeffler said, "Superior tuning repeatability and linearity reduce the uncertainty of all wavelength-dependent tests"—thereby reducing guardbands and increasing manufacturing yield.

Loeffler said the company's tunable laser expertise goes back to the step-tunable HP 8161A in 1992. In fact, he said, "Since the HP 8153A lightwave multimeter, our first two-slot mainframe introduced in 1990, we have furnished component manufacturers, researchers, and developers working in photonics and fiber optics with an ever-growing modular test-equipment portfolio, complemented by signal generation and analysis test gear for the terabit era."

Compared with the current 81600B laser, which Loeffler called the industry standard for more than a decade, the 81606A tunable laser offers these features:

- 15 dB more dynamic range through higher signal power with lower spontaneous emission, enabled by the new cavity and laser module design;
- fourfold improvement in absolute accuracy with increased real-time tracking speed and resolution, enabled by the novel wavelength reference unit; and
- 40 times faster sweeps without impacting the specified dynamic accuracy, enabled by enhanced feedback controls and drive mechanics.

"When component developers validate their designs, they want to get maximum confidence from their measurements in virtually no time," said Dr. Joachim Peerlings, marketing manager of Keysight's Digital and Photonic Test Division, in a press release. "We designed the 81606A tunable laser source with that goal in mind. An innovative, autonomous wavelength reference unit and a new cavity design push current benchmarks for measurement accuracy, dynamic range, and test time while ensuring the highest long-term stability and enabling cost-efficient servicing."

Oscilloscope enhancements

Teledyne LeCroy chose the OFC to announce enhancements to the two highest performance oscilloscope product lines in the company's portfolio **(Figure 2)**. The new 10 Zi-A delivers improved performance in effective number of bits and baseline noise. The WaveMaster 8 Zi-B features increased sample rate, lower noise, enhanced processing capabilities, and the latest version of Teledyne LeCroy's advanced oscilloscope user interface, MAUI.

Figure 2. 10-Zi-A and 8-Zi-B oscilloscopes
Courtesy of Teledyne LeCroy

The 10 Zi-A builds on the 10 Zi oscilloscope series. The new models include improvements in signal fidelity and noise performance while maintaining performance with respect to bandwidth (100 GHz), sample rate (240 GS/s), and intrinsic (sample clock) jitter (50 fs).

The 10 Zi-A's modular ChannelSync architecture lets users build oscilloscopes with up to 80 channels with better than 130-fs channel-to-channel jitter. Serial data and optical modulation measurement toolkits, including SDAIII-CompleteLinQ and Optical-LinQ, provide a set of tools for advanced analysis. A new PAM-4 package supports real-time oscilloscope analysis

of systems using PAM-4 signaling. These capabilities coupled with the performance enhancements make the 10 Zi-A suitable for engineers designing next-generation high-speed electrical and optical links.

The updated WaveMaster 8 Zi-B enhances the capabilities of its predecessor with lower noise, higher sampling rates, deeper acquisition memory, and the next-generation of Teledyne LeCroy's MAUI oscilloscope user interface. SDA 8 Zi-B Serial Data Analyzer models are specifically configured for testing today's high-speed electronics systems, with an advanced eye and jitter analysis toolkit, additional acquisition memory, and a true hardware serial data trigger. When coupled with Teledyne LeCroy's standard-specific analysis options, the SDA 8Zi-B is suitable for testing, characterizing, and debugging USB 3.1, PCI Express, DDR memory, MIPI M-PHY and D-PHY, and other applications.

The U.S. list prices for the 10 Zi-A system start at $215,885. 10 Zi-A systems include either an MCM-Zi-A or SDA MCM-Zi-A along with at least one acquisition module and are available with bandwidths ranging from 20 GHz to 100 GHz. Delivery time is approximately six to eight weeks ARO. WaveMaster 8 Zi-B and SDA 8 Zi-B oscilloscopes are available with bandwidths ranging from 4 GHz to 30 GHz. WaveMaster 8 Zi-B US list prices start at $75,600; SDA 8 Zi-B U.S. list prices begin at $90,600. Delivery time is approximately six to eight weeks ARO.

O/E calibration module for VNAs

Anritsu introduced the MN4765B O/E Calibration Module **(Figure 3)** for its MS4640B Series VectorStar vector network analyzers (VNAs), creating a cost-effective and flexible solution for measuring 40-Gb/s components and transceivers. Serving as an optical receiver, the MN4765B allows engineers to use the MS4640B Series to perform accurate and stable optoelectronic measurements on laser modulators and photoreceivers during R&D and manufacturing. The MN4765B also can be used with the VNA to characterize optical transmitters, receivers, and transceivers.

Magnitude and phase characterization is obtained using a primary standard characterized by NIST and conducted in the Anritsu calibration lab. The result is improved measurement uncertainty when the MN4765B is used with VectorStar across the VNA's 70-kHz to 70-GHz frequency range. The MS4640B Series VectorStar VNAs, when calibrated using the MN4765B module, enable error-corrected transfer function, group delay, and return-loss measurements of E/O and O/E components and subsystems.

The MN4765B module is thermally stabilized to eliminate drift in photodiode performance over temperature and designed with additional circuitry for temperature and bias stability. The InGaAs photodiode has a bandwidth response to 70 GHz and a typical responsivity of 0.7 A/W.

Figure 3. MN4765B O/E calibration module for the MS4640B Series VectorStar VNAs
Courtesy of Anritsu

The MN4765B module complements the overall performance of the MS4640B VectorStar VNA, which offers the 70-kHz to 70-GHz coverage and can extend coverage to 145 GHz in a broadband configuration. The MS4640B VNA also has a dynamic range of up to 142 dB.

Anritsu also showcased technologies and test solutions for engineers who are designing emerging high-speed transmission products and systems utilizing technologies from 400 Gb/s to 1 Tb/s for applications in the lab, the production floor, and the field.

For R&D applications, Anritsu highlighted its MP1800A BERT signal quality analyzer and MP1825B 4Tap Emphasis. The test solutions will be configured as an ultra-high-speed transmission test system operating up to 1 Tb/s with multichannel synchronization signals, such as Quad DP-16QAM and Dual DP-64QAM. Anritsu also featured a 400+G Super Channel test solution that will combine the company's MZ1834A 4PAM Converter with the MP1800A to generate 4PAM signals.

For 400-Gb/s Ethernet and 100-Gb/s design and manufacturing environments, Anritsu presented the Network Master Flex MT1100A. This portable transport tester supports simultaneous installation of four independent 100 Gb/s ports, and it can send and receive a variety of 100 Gb/s × 4 client signals to test 400 Gb/s network and transport equipment for Optical Transport Network (OTN) applications.

For field optical test, Anritsu presented the MT1000A Network Master Pro, which supports OTN, MPLS-TP, and Ethernet as well as Fibre Channel, SDH/SONET, and PDH/DSn.

50-GHz electro-absorption modulator

In other news at OFC, nanoelectronics research center imec, its associated lab at Ghent University (Intec), and Stanford University demonstrated a compact germanium (Ge) waveguide electro-absorption modulator (EAM) with a modulation bandwidth beyond 50 GHz. Combining state-of-the-art extinction ratio and low insertion loss with an ultra-low capacitance of just 10 fF, the demonstrated EAM marks an important milestone for the realization of next-generation silicon integrated optical interconnects at 50 Gb/s and beyond.

Future chip-level optical interconnects require integrated optical modulators with stringent requirements for modulation efficiency and bandwidth as well as for footprint and thermal robustness. In the presented work, imec and its partners have improved the state-of-the-art for Ge EAMs on Si, realizing higher modulation speed, higher modulation efficiency, and lower capacitance. This performance was obtained by fully leveraging the strong confinement of the optical and electrical fields in the Ge waveguides as enabled in imec's 200-mm Silicon Photonics platform. The EAM was implemented along with various Si waveguide devices, highly efficient grating couplers, various active Si devices, and high-speed Ge photodetectors, paving the way to industrial adoption of optical transceivers based on this device.

"This achievement is a milestone for realizing silicon optical transceivers for datacom applications at 50 Gb/s and beyond," stated Joris Van Campenhout, program director at imec, in a press release. "We have developed a modulator that addresses the bandwidth and density requirements for future chip-level optical interconnects," he said.

Companies can benefit from imec's Silicon Photonics platform (iSiPP25G) through established standard cells or by exploring the functionality of their own designs in Multi-Project Wafer runs. The iSiPP25G technology is available via ICLink services and MOSIS, a provider of low-cost prototyping and small-volume production services for custom ICs. **EE**

Reference

1. "Upbeat Mood at OFC Signals Market Potential," *OFC Blog*, March 26, 2015.

Switching System Test Tools

The eBIRST diagnostic test tools, designed specifically for the vendor's PXI, PCI, or LXI (Ethernet) products, simplify switching system fault finding by quickly testing the system and identifying the faulty relays. Once the relays are identified, the tools then display a graphical representation of the switching system's PCB assembly, highlighting the relays that need to be replaced. The eBIRST tools achieve this task by measuring the path resistance between different pins on the switching system connector and controlling the path through the system to allow it to test any of the relays in the system. Systems that use separate input and output connections can be tested by use of two eBIRST tools in a master/slave configuration.

The application program, which is free to download from the Pickering Interfaces website, is regularly updated to include support for a growing range of Pickering Interfaces switching products. **Pickering Interfaces, www.rsleads.com/506ee-201**

Immunity Test System

The NSG 4060 complies with current testing standards including EN 61326-3-1, IEC 61850-3, IEC 60255-22-7, IEC 60533/IEC 60945, IEC 61000-4-16, and IEC 61000-4-19 and meets the new requirements for immunity testing to low-frequency disturbances in the frequency range of 15 Hz to 150 kHz. Suitable for use by manufacturers of smart electrical meters, industrial circuit breakers, and industrial Ethernet and shipboard equipment, the NSG 4060 is a robust system with an intuitive front panel that enables the unit to run fully compliant tests without a PC. It accurately tests low-frequency immunity in common and differential mode.

The NSG 4060 shares the same chassis and user interface as the NSG 4070 RF conducted immunity system, featuring a 5.7-inch color display and hard keys for important functions. A user manual with extensive set-up diagrams and instructions is included with each unit. **Teseq, www.rsleads.com/506ee-202**

Real-Time Spectrum Analyzer

The compact RTSA7500 real-time spectrum analyzer analyzes wireless signals in real time. The RTSA7500 has the standard features of a sophisticated, expensive benchtop spectrum analyzer but at lower cost since it uses the display and processing power of an attached PC. Frequency controls, marker functions for tracking specific frequencies, and multitrace functionality are all included as well as real-time triggering for measuring complex data signals such as Wi-Fi and LTE. FPGA-based digital signal processing within the RTSA7500 enables the capture of elusive time-varying signals across an instantaneous bandwidth of up to 100 MHz.

The instrument is manufactured by Berkeley Nucleonics. **Saelig, www.rsleads.com/506ee-203**

DAQ Controller

A new CompactDAQ eight-slot controller expands the CompactDAQ controller offering to meet high-channel-count applications in rugged environments. By integrating the processor, signal conditioning, and I/O into a single CompactDAQ system, engineers can decrease overall system cost and complexity while increasing measurement accuracy. Integrated measurement systems reduce the number of components, connections, and wiring needed, which often introduce noise and additional costs, to ensure high-accuracy measurements and cost-optimized systems.

Both the four-slot and eight-slot CompactDAQ controllers feature an Intel Atom dual-core processor that can run either Windows Embedded 7 or NI Linux Real-Time. By pairing industry-standard OS options with LabVIEW system design software, customers can easily port LabVIEW code from existing measurement systems to these new CompactDAQ controllers. They can combine LabVIEW and more than 60 sensor-specific I/O modules for CompactDAQ to quickly customize data acquisition systems to meet their application needs. **National Instruments, www.rsleads.com/506ee-204**

Sound and Vibration System

VIBbox is a complete portable system with 64 IEPE input channels, eight stimulus D/A channels, four tachometer channels, and a plethora of digital I/O, counter/timer, and measure-counter channels. Being a parallel measurement system, VIBbox features simultaneous measurement from all channels. IEPE inputs from sensors such as microphones and accelerometers that have a large dynamic range can be connected directly and executed at a very fast throughput of 105.4 kHz. Common applications include audio, acoustic, and vibration testing.

VIBbox operates using the ready-to-measure QuickDAQ application with the Advanced FFT Analysis Option as a standard. The easy-to-use QuickDAQ application acquires data, analyzes the data, records the data to disk, and displays and plots the results. VIBbox is available at $24,995. **Data Translation, www.rsleads.com/506ee-205**

LCR Meter Options

Three low-frequency options for the E4982A LCR meter enable RF inductor, coil, and EMI filter manufacturers to perform impedance testing at various frequencies. Today's smartphones and other electronic equipment often utilize components such as inductors and EMI filters. Ensuring these passive components operate as expected in the real world requires impedance testing during production as well as during quality assurance.

The options cover the 1-MHz to 300-MHz (Opt. 030), 500-MHz (Opt. 050), and 1-GHz (Opt. 100) frequency ranges. These new frequency range options complement the E4982A's existing 3-GHz measurement capability (Opt. 300). Frequency upgrade options also are available.

The low-frequency options' base prices are as follows: E4982A-030, 1 MHz to 300 MHz—$16,012; E4982A-050, 1 MHz to 500 MHz—$18,801; and E4982A-100, 1 MHz to 1 GHz—$27,375. **Keysight Technologies, www.rsleads.com/506ee-206**

Source-Measure Unit

A new addition to the GS820 source-measure units, all of which feature isolated two-channel source and measurement functions, is able to source up to 50 V and 0.6 A DC. The SMUs offer four-quadrant operation consisting of current source and current sink operation. On the 50-V model, voltage ranges are 200 mV, 2 V, 20 V, and 50 V. Current ranges are selectable from 200 nA to 1 A.

Applications for these source-measure units include tests for LED lighting and the generation of I/V curve traces for LEDs and varistors. The basic price for the new 50-V two-channel Model GS820 is $9,490. **Yokogawa Corp. of America, www.rsleads.com/506ee-207**

USB 3.1 Test Suite

The QPHY-USB3.1-Tx-Rx package performs automated USB 3.1 transmitter (Tx) and receiver (Rx) compliance testing, characterization, and debug, creating a comprehensive USB 3.1 test suite. With the new test package, USB 3.1 testing can be conducted on both Gen1 (5 Gb/s) and Gen2 (10 Gb/s) devices under test according to the latest USB 3.1 specifications. Tx testing is performed using a high-bandwidth 16-GHz oscilloscope while Rx testing uses the Protocol Enabled Receiver and Transmitter Tolerance Tester (PeRT3). The new QPHY-USB3.1-Tx-Rx software leverages the QualiPHY automated test framework, which provides connection diagrams, automated oscilloscope operation, and report generation.

QPHY-USB3.1-Tx-Rx is available for $8,000. Oscilloscopes capable of testing USB 3.1 start at $158,900, and a PeRT3 capable of testing USB 3.1 starts at $182,000. **Teledyne LeCroy, www.rsleads.com/506ee-208**

40-GHz RF SOI Switch

The UltraCMOS PE42524 RF SOI (silicon-on-insulator) switch operates up to 40 GHz, significantly extending the vendor's high-frequency portfolio into frequencies previously dominated by gallium arsenide (GaAs) technology. As an alternative to GaAs-based solutions, the PE42524 features high reliability and performance advantages in linearity, isolation, settling time, and ESD protection. These attributes make the switch suitable for test and measurement, microwave-backhaul, radar, and military communications devices. **Peregrine Semiconductor, www.rsleads.com/506ee-210**

EE LITERATURE MARKETPLACE

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AR RF/Microwave Instrumentation	http://bit.ly/amplifierfundamentals	39
CertifiGroup	www.CertifiGroup.com	39
CHROMA Systems Solutions, Inc.	chromausa.com	15
Data Translation	www.datatranslation.com	17
Educated Design & Development. Inc.	www.ProductSafet.com	39
Keysight Technologies	www.keysight.com/find/PAM-4-insight	6-7
Keysight Technologies	www.keysight.com/find/5G-Insight	8-9
Keysight Technologies	www.keysight.com/find/SeeTheWork	13
Keysight Technologies	www.testequity.com/Agilent_DMM	21
Keysight Technologies	www.keysight.com/find/triggerchallenge	27
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Measurement Computing Corp	www.mccdaq.com	16
National Instruments	ni.com/automated-test-platform	3
Pickering Interfaces Inc.	www.pickeringtest.com/ebirst	5
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Saelig Company, Inc.	www.saelig.com	20
SEMICON West 2015	www.semiconwest.org	31
Sensors Expo & Conference	www.sensorsexpo.com	33
Stanford Research Systems	www.thinkSRS.com	IBC
Vibration Test Systems	www.VTS2000.com	30
Yokogawa Corp of America	tmi.yokogawa.com	11

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By Tom Lecklider, Senior Technical Editor

Managing EMC and wireless test

Bryan Sayler
Vice President
Solutions Development
ETS-Lindgren

Bryan Sayler, a 27-year veteran of the EMC industry, is vice president for solutions development at ETS-Lindgren, with duties that include identifying marketing trends for the company. He started his EMC career with Rayproof, a pioneering anechoic chamber and absorber company. Initially, Sayler managed anechoic chamber manufacturing, eventually having responsibility for shielding as well. Several years later, Escorp bought Rayproof and combined it with Rantech and the Electromechanics Company (EMCO), both already owned by Escorp, to create EMC Test Systems, or ETS. In 2000, the Lindgren company was added, forming the present ETS-Lindgren.

As Sayler explained during an interview at the recent IEEE Electromagnetic Compatibility and Signal Integrity Symposium, the basis of the company through about 2000-2001 had always been shielding and absorbers, often combined in chambers. The Lindgren company brought with it very interesting new MRI and electron microscope applications, but shielding remained central. Of course, forming ETS-Lindgren integrated not just the two groups of products, but also the company cultures.

The turning point occurred when, as Sayler recounted, "We were approached by one of our major customers that wanted us to build everything, including the software, necessary to make wireless OTA measurements for cell phones." And as they say, the rest is history.

The cell phone work was successfully completed, resulting in the initial version of ETS' EMQuest wireless test software. A few years later, the TILE! Program was redeveloped as a comprehensive test executive, specifically for EMC engineers. Today, the opportunities that ETS pursues often result from its capabilities in both the wireless and EMC fields.

For example, Sayler described the growth ETS currently is experiencing in Asia—the most rapidly growing of the international areas making up about 45% of the company's sales. Some of the infrastructure investments aid product research and development. But on the EMC side, Sayler said, test facilities are being built so that companies can do their own testing inhouse, avoiding the delays associated with a U.S. or European lab. He said, "In China in particular, that's the kind of cycle that we're in now. A lot of companies are building their own chambers to be able to do good product development and export beyond just that market …. Using either the TILE! Software for EMC or the EMQuest software for wireless, we're able to provide a complete end-to-end solution for a customer."

To support increased activity in international markets, ETS-Lindgren has eight factories worldwide. Almost all of them have some shielding capability because that's the largest volume product. The absorber is made in Oklahoma. Sayler continued, "We do our own research and development and have quite a capable team for dealing with not only the chemical properties of the foam, but also the mathematical modeling of the shapes."

In addition to local factories, the company has established several overseas subsidiaries. Sayler explained, "In China, we have a wholly owned foreign entity—ETS-Lindgren China. In India, we have the same. In Tokyo, we have a legal entity ETS-Lindgren Japan. In Singapore and Taiwan, we have offices that are part of our U.S. business. Based on market size, sometimes we'll work through a distributor, and sometimes we'll work direct."

Beyond shielding and absorbers, ETS also manufactures antennas, field probes, line impedance stabilization networks, GTEMs, reverberation chambers, and full anechoic chambers. Of course, few companies, including ETS, actually make all the parts of a complex test system. Sayler discussed the advantages of working with a number of well-established companies to provide the best solution for each customer. He said, "We have a number of partners that we work with, such as Rohde & Schwarz, Keysight Technologies, and Anritsu—major instrument suppliers. If they have equipment that is useful and preferred by the customer, we'll integrate that into our system."

Continuing with the theme of system integration, the company's recently introduced line of amplifiers has been well received, according to Sayler. He elaborated: "We don't specify our amplifiers the same way that other companies do. We don't talk as much about output power because output power is useful only if you need it. What we talk about instead is the delivered field strength." He continued, "We have control over the design optimization of the amplifier and the chamber. If your chamber isn't designed well, you can get a lot of reflections that will have an impact on your system. By designing a better chamber and a great antenna, we're able to do more with less in terms of the amplifier size."

Perhaps the largest current opportunity is in the automotive industry, where EMC and wireless are converging. Sayler described the use of as many as 20 or 30 antennas in a high-end car to deal with satellite radio, LTE, tire-pressure monitoring, and front and rear radar collision avoidance systems. He explained, "We've set up a group inside ETS-Lindgren to focus specifically on this because the way an automotive company thinks about their antennas is different from the way a cell phone company would think about their antennas, but they have the same problem."

Sayler is in a unique position to understand and respond to customer needs, being responsible for identifying market trends, developing specific solutions, and implementing them via a project management team that handles all aspects "from cradle to grave." In addition to Sayler, ETS has separate manufacturing and sales managers, also with worldwide responsibilities.

Within ETS, marketing's role, as Sayler described it, "… is to help connect our customers to our capabilities. Most of the time, our customers don't fully appreciate all of the things that ETS-Lindgren can do …. They either think of us as a shielding company or as a software company, or as an antenna company …. Marketing's job really is to help customers grasp the totality of what ETS-Lindgren can do for them." **EE**

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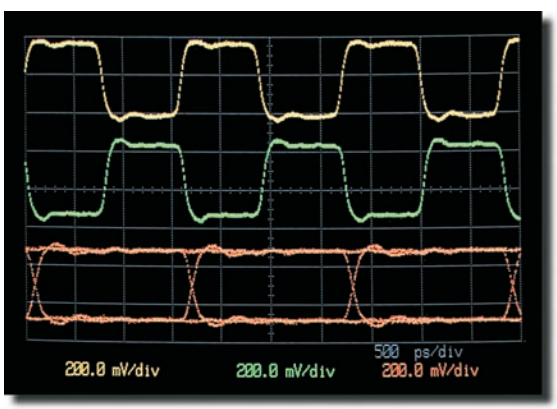

Plot shows complementary clocks and PRBS (opt. 01) outputs at 622.08 Mb/s with LVDS levels. Traces have transition times of 80 ps and jitter less than 1 ps (rms).

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